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CONIFER PLANTATIONS AS WILDLIFE HABITAT[1]

obert Leo Smith Assistant Professor of Wildlife Management
West Virginia University

ABSTRACT

e purpose of this study was to determine the effect of conifer reforesta- wildlife distribution and to draw some conclusions regarding basic ment practices that might improve wildlife use of plantations. Sixty-two ons, involving 10 species of conifers in mixed and pure plantings, and g various height and age classes, different acreages and a variety of nditions, were studied. The areas were visited on foot during all seasons tain comparative game use of various plantations.

succession of wildlife, associated with increasing height, occurs in d areas. As the height and cover density of the plantations increase, ld forms of wildlife are replaced by shrubland forms. These in turn tually replaced by forest species.

ferences of different wildlife species for certain conifers and the growth r of various trees influence the wildlife use of plantations, especially in beyond 12 feet. Deer showed a strong preference for pine in winter, ummer they frequented all plantations. Since the lower limbs of spruce ried under several feet of snow, creating tent-like shelters beneath the pruces proved the most effective winter cover for rabbits and grouse. made little use of plantations in summer; most individuals observed were ings or in fire lanes. Grouse nests and broods were found in spruce and plantations.

e distribution and abundance of wildlife in a plantation is influenced area, nature of the edge, presence, size and abundance of openings. ons over 10 acres held a greater variety of wildlife and larger popula- an did smaller plantations. Such plantations offer forest-like conditions ariety of habitat situations, especially if the stands are of uneven age enings exist. Locust blocks and lanes in plantations stimulated dense of bramble and grass that furnished both cover and food high in . Wildlife use of smaller plantations is largely dependent upon adjacent Groups of small plantings were used more consistently by grouse and an isolated plantings. Cottontail rabbits benefited the most from small s.

nagement practices, based on observations made in the plantations are suggested. Large plantations should contain a variety of openings ill produce food for game. Inclusion of black locust, planted either in r in lanes, seems desirable wherever the species has a reasonable chance opment. Fire lanes increase the amount of edge in large plantations. nd marshes can add materially to the attractiveness of plantations to Small plantings are most useful if planted close to adjacent cover and t in groups instead of isolated stands. Mixed plantings are more desirable

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than pure plantings of any one type of conifer. Each type should make u fairly wide band or block. Areas planted to pines alone will usually be benef by surrounding them with several widely spaced rows of spruce. Spacing t 10 by 10 feet is recommended to maintain the suitability of a planting for s game over a longer period. Stands of uneven height are more desirable s these provide a wide variety of habitat conditions. Where wildlife values ar be emphasized, pruning and thinning should be restricted to benefit crop t primarily except in Scotch pine, jack pine and larch plantations, and hardw growth should be allowed to grow and even be encouraged in as many pl as possible.

Widespread planting of conifers on abandoned agricultural l under the State's reforestation program began more than three deca ago and has continued to the present. Some have been led to bel that large areas of little use to wildlife were being created. Recen the great increase in tree planting on private lands developed un the wildlife habitat restoration (Federal Aid Project W-48-D) prog has caused others to question whether such large-scale conifer plan would improve wildlife habitat and, if so, in what ways. In orde determine the effectiveness of this program, an evaluation study established by the New York State Conservation Department un the direction of Dr. Oliver H. Hewitt of Cornell University. T paper is a report on a study of conifer plantations as wildlife hab made from February 1954 to June 1956. The purposes of the st were: (1) to determine the influence of such plantations on wild in respect to species of conifer and to the area, location, height condition of a plantation; (2) to determine how present planta management influences the wildlife use of plantations; (3) to d some conclusions regarding basic management practices that m further develop their wildlife values.

There are few accounts in the literature of planned studies on wildlife communities of coniferous plantations in this country or the effects of reforestation on wildlife. The first and principal w of importance on the subject of reforestation and wildlife in the Nor east was that reported by Edminster (1935). Edminster conducte survey in July 1933 and January 1934 on the Luther Forest Pres between the Mohawk valley and the Adirondack Mountains in eas New York. Here he compared natural versus reforested areas. plantings consisted of large blocks of even-aged conifers, 12 to years old, established on a flat terrain of sandy soil. The plan success was remarkably high, approaching 100 per cent, either original survival or fill-in planting. All of his measurements w taken from the outside edge of solid stands of conifers approac

exceeding 100 acres in extent. He concluded that the type of restation found there was unsatisfactory for ruffed grouse *(Bonasa bellus)* because it provided insufficient amounts of needed cover uirements for the summer months, but that it was satisfactory at time for cottontail rabbits *(Sylvilagus floridanus)*. He found that 3 per cent of the rabbits and no grouse at all occurred more than feet within the plantations he studied and that no deer *(Odocoileus inianus)* or gray squirrels *(Sciurus carolinensis)* penetrated over feet into the area. He observed that the use of these plantings game species, even as winter shelter, diminished as they exceeded feet in diameter, and that portions which lay more than 300 feet n an edge were in effect of no use to wildlife. He estimated that method of reforestation reduced the wildlife potential of the ited area from 50 to 75 per cent in terms of plantations 20 years nore old, and he concluded that, in general, the only wildlife value uch stands is shelter during winter and that this is effective only depth of 200 feet. He recommended that solidly planted units r exceed 600 feet in diameter, preferably not over 400 feet, and such units be separated by hardwoods and food-bearing shrubs by open land in narrow concentric strips.

Gray and Hermal (1939) surveyed the game cover and openings ne Buck Creek plantations in the Huron National Forest in Michi- Here they compared the plantation and natural stands which e very similar in respect to species, both consisting primarily of pine *(Pinus banksiana)* and oak *(Quercus* spp.*)*, and in respect he number of openings. Although they felt that their wildlife nts were not sufficiently accurate to be conclusive, it appeared that small game and fur-bearer populations in the planted areas were greatly different from those in the natural areas. The plantations ney existed seemed to provide a pattern of openings which could cely be improved upon if they had been deliberately planned.

Hosley and Ziebarth (1935) made observations on the use of fers and a coniferous plantation by deer in northwestern Massa- setts during the winter of 1933-34. The deer showed a strong erence for bedding in the coniferous types. Nearly half of the beds e located in the natural white pine *(Pinus strobus)* stands 15 to ears of age, and about a fourth of them were in a 15-year-old ch pine *(Pinus sylvestris)* plantation. The latter furnished food over a week at a time, especially during March.

Allen (1938) in a study of farm wildlife in Kalamazoo County ch.) observed that ring-necked pheasants *(Phasianus colchicus)*,

especially cocks, and rabbits were present about small planting summer and that both favored conifers as winter cover.

Considerably more attention has been given the faunal composi of conifer plantations by European workers, since plantations form important part of their forests and forestry program. Although t studies have dealt primarily with passerine birds, many of their f ings are applicable to game species. They have reported the var and density of birds to vary with the species of conifers, openi presence of undergrowth and broadleafed trees, stage of grov methods and degrees of thinning, proportion of edge to the w area, density of overhead cover, nesting sites and other factors (L 1933, 1939; Lack and Lack, 1951; Mackenzie, 1945).

STUDY AREA

The region in which the major portion of this study was m included the southern half of Tompkins County and the north quarter of Tioga County. This region is typical of the highland southern New York, having large tracts of abandoned or se abandoned land with active farms interspersed on the better s It is representative of the glaciated Allegheny Plateau in southern N York and northwestern Pennsylvania. The region is very hilly. tops of the hills are nearly level or gently rolling, the bordering up slopes are relatively steep, and the lower slopes are smooth and ge In some places the stream valleys are deeply cut, with their sides s or even precipitous.

The plantations chosen for study were located on two S reforestation areas, the Connecticut Hill Game Management Area, private lands within a 15-mile radius of Ithaca, New York. The st areas were representative of land on which reforestation is likel continue.

State Reforestation Areas

The State reforestation areas involved in this study are loc in the town of Caroline, Tompkins County. Agriculturally, it is of the poorest towns in the county. Most of the farms are abando except in the valleys. One-third of the town consists of State county lands. Abandonment had begun by the early 1900's and 1927 two-fifths of the houses and half the barns were gone or sidered unusable (Vaughn, 1929). Today most of the houses people are gone.

Tompkins Area No. 3 (Figure 1) is located approximately 1½ south of Caroline Center. Most of the plantations were established in 1935. A number of new plantations have been established recent years. The elevation ranges from 1,200 to 1,750 feet above

e 1. Part of Tompkins Area No. 3. In the middle foreground are a jack pine, a Scotch pine and a larch plantation.

level. The soils were originally classified as Lordstown, Volusia Allis. Although the area has not been resurveyed, these same soils y probably would be classified in the Lordstown, Mardin, Volusia Chippewa series. The plantations included pure and mixed plantof white cedar (*Thuja occidentalis),* Scotch pine, jack pine, red (*Pinus resinosa),* white pine, Norway spruce *(Picea abies),* white ce *(Picea glauca),* European larch *(Larix decidua),* balsam fir es *balsamea),* and black locust *(Robinia pseudoacacia).* Indial plantations varied from 8 to 90 acres. Many of these joined another to form a continuous planting over several hundred acres. Tompkins Area No. 4 (Figure 2) is located 2 miles south of line Center. The elevation ranges from 1,650 to 1,740 feet. In ral, the land is not as steep as that of Tompkins Area No. 3 and

Figure 2. A pine-spruce-larch plantation on Tompkins Area No. 4.

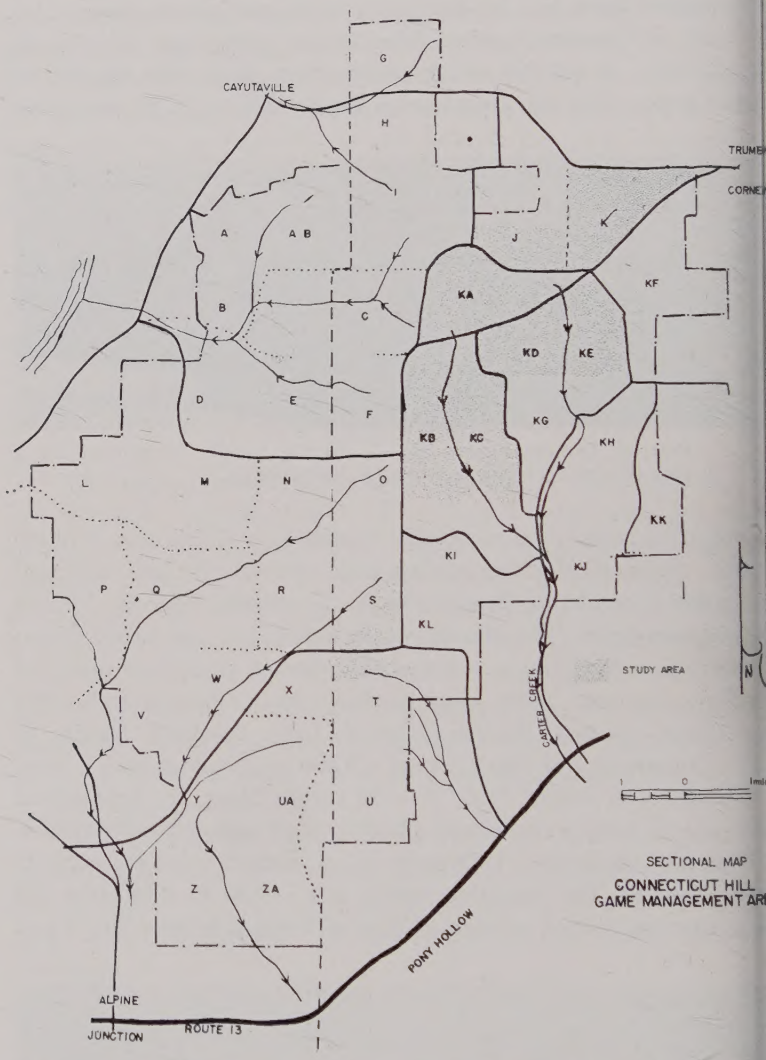

Figure 3. Map of Connecticut Hill Game Management Area showing port used as study area.

much of it is more poorly drained. Most of the plantings were est lished in 1939 and occur on soils that probably would be classi as Volusia or Chippewa. The plantations consisted of pure and mi plantings of Scotch pine, white pine, red pine, Norway spruce, w cedar, and Douglas fir *(Pseudotsuga menziesii)* and ranged from

4 acres. Here again many of the plantations joined one another rm continuous plantings over much of the area.

NECTICUT HILL GAME MANAGEMENT AREA

The vegetation and other characteristics of Connecticut Hill ure 3) were well described by Bump (1948, 1950) and Bump '. (1947). The area, near Newfield, was acquired by the New State Conservation Department for game management purposes. equent development included the establishment of a game refuge, t stand improvement, reforestation, and small marsh and pothole lopment. The plantations were small, well distributed (Figure 4)

e 4. View of Sections KA and KE on Connecticut Hill Game Management Area showing distribution of plantations.

consisted of red pine, white pine, Scotch pine, jack pine, and way spruce. They ranged in size from 1 to 55 acres. Open land overgrown fields were scattered. Much of the upland is level or ly sloping, and the stream valleys are steep-sided. The highest t is 2,097 feet and the lowest is 1,300 feet. The soils belong to the lstown, Mardin, Volusia and Chippewa series.

CELLANEOUS AREAS

Others included a 43-acre white spruce plantation on State lands les southwest of Danby, the Cornell plantations near Varna, and al pine and larch plantings (some of which were established with eral Aid funds) on private lands in Tompkins and Tioga Counties.

PROCEDURE

Because of the paucity of information on conifer plantation-

wildlife relationships, observations were spread over many plantatio rather than concentrated in a few. Since the original distribution a abundance of wildlife present prior to planting was unknown, the re effect of any one plantation on the wildlife of that area throughout t years could not be measured. Some idea, however, of the effect plantations on wildlife could be determined by observing and co paring wildlife use of plantations of different acreages, species a heights already in existence.

In all, a total of 62 plantations, embracing a variety of spec of conifers in pure and mixed plantings and a wide range of acreag height, survival and edge conditions, were studied.

All areas were cover mapped and the history of each plantati was secured. Plantings were visited on foot during all seasons. A attempt was made to spend an equal amount of time in each in pr portion to its area. All were visited frequently enough to determi comparative game use and seasonal population shifts. Actual observ tions, track counts, pellets, scats, and other signs gave an indication comparative abundance and use. For lack of time and addition assistance, none of the intensive small game census techniques we used. In spring, summer and fall, survey lines 50 yards apart we walked through each plantation. During winter these survey lin were sometimes only partially covered since ice and snow imped travel, even with snowshoes. Areas and sign of activity were locat on field maps during each visit. Quadrat studies of ground cover we made in jack pine, Scotch pine and red pine plantations.

FINDINGS

The influence of reforestation on wildlife is subject to the inte action of a number of factors including the nature of the site and su plantation characteristics as species composition, age, height, conditio edge and others. The observations made during this survey are pr sented and discussed in relation to these factors. It should be e phasized again, however, that the areas studied represent submargin lands, largely abandoned, such as are common at higher elevatio throughout southern New York, and that the findings apply primari to this type of range.

Wildlife Succession in Plantations

The effect of land abandonment on wildlife is influenced by t stage and rate of plant succession and the size of the area. Because

dependence upon plants for food and cover, wildlife populations closely associated with these changing plant communities. On small doned areas surrounded by brush and forest, the successional ges from open field to a stand of temporary trees such as aspen birch may be quite rapid. Where large areas are abandoned at , as has occurred in southern New York, the seed sources are far removed. Frequently from 50 to 60 years may be required tands of aspen, birch, maple or pine to develop.

With reforestation this whole pattern is changed. Succession is led up. Instead of 6 to 15 years as usually required, the shrub is reached in 5 to 8 years when the conifers are 6 to 10 feet in t. In 20 to 25 years the area is in forest, but in place of the deciduous community is a coniferous stand.

The effect of plantations on the wildlife use of an area, as con-d with the effect of normal plant succession, is very great. In al, a succession of wildlife associated with height occurs (Figure This is especially pronounced in passerine birds (Smith, 1956).

The wildlife of open land, characterized by such species as the ntail rabbit and ring-necked pheasant, is affected little by plant-until the trees reach about 4 feet in height. From this stage on, itions begin to deteriorate for pheasants but are continually oving for rabbits. When a plantation reaches 10 to 15 feet, the is much like that of a thickly overgrown field but has considerably effective cover. Usually the crown has not closed so tightly that minates all herbaceous ground cover, and the low branches of onifers still remain. This combination of branches close to the d and many small islands of old field vegetation still attracts ts. Ring-necked pheasants frequent the edges if suitable habitat acent to the planting. At this stage the ruffed grouse appears.

When a plantation reaches 20 to 25 feet, significant changes take . The crown closes and the lower limbs die. The herbaceous ation of the field is eliminated except under certain conifers such k pine and larch. Openings occur from blowdowns, storm and damage, and the failure of some trees to survive. A variety of and edge situations exists. It is at once part field and part forest. its still remain about the edges and in the openings, provided is a sufficient food supply. The gray fox *(Urocyon cinereoargen-* may appear. Ruffed grouse nest in the openings and use the for winter cover. White-tailed deer use the plantation heavily onsistently throughout the year.

Figure 5. Wildlife succession in conifer plantations in Central New York.

As the trees mature, more and more lower limbs and undercover ppear. Rabbits use the area only for travel lanes. The gray fox, fox (*Vulpes fulva*), red squirrel (*Tamiasciurus hudsonicus*) and e-tailed deer are the principal wildlife inhabitants.

In winter the wildlife occupying the plantation is also influenced eight. Cottontail rabbits are found in plantings offering suitable , i.e., stands ranging from 6 feet to a height where the maturing ers no longer supply ground cover. Ruffed grouse frequent ations from 12 to 35 feet in height. White-tailed deer seek cover antations over 20 feet tall. Plantations of lower height are gen- avoided because of poor snow interception and impediment of ment.

This is a very generalized picture of wildlife succession in conif- plantations. Use of any one plantation is influenced by secondary rs such as the species of conifer involved, the area, and the nature e surrounding cover and openings.

UENCE OF CONIFEROUS SPECIES ON WILDLIFE USE

At the beginning of the study it was believed that the species of r was of little importance in relation to the wildlife occupying ntation; but as the study progressed it became obvious that certain fe species prefer certain conifers, and that the growth behavior rious trees strongly influences the wildlife potentialities of a planta- Use also varied with the season.

Foxes, both red and gray, were the chief predators inhabiting all e plantations. The red fox was more common on Connecticut where the plantings were smaller and considerable open land d. Both species were present on the State reforestation areas e hundreds of acres were in plantations. Foxes ranged widely gh all plantations and dens were found in all types of plantings. inter as the spruce branches became pinned to the ground by foxes systematically searched the pockets beneath the spruce for small mammals and other prey. As the depth of the snow beyond 1½ and 2 feet, this type of hunting became difficult abbits, grouse and small mammals were rather secure. Trapping the State rabies control program during the summer of 1955 th the State reforestation areas studied reduced the fox popula- ae following winter.

The coniferous trees used in reforestation can be divided into three classes in respect to growth form and general growth behavior:

1. The pines with straight, cylindrical trunks, whorled spreadi branches and a crown density that varies with the species.
2. The spruce-fir group, including the spruces, balsam fir, a Douglas fir, with more or less tall pyramidal dense crow straight, gradually tapering trunks, and whorled horizon branches.
3. The larches with tall pyramidal open crowns, slender pend lous horizontal branches irregularly disposed, and a decidu habit.

In the lower height classes, up to 12 feet, there is little differe in the wildlife use of plantations of any species. When plantati grow beyond this height pronounced changes in use occur.

The Pines Red pine and Scotch pine plantations with tr over 20 feet in height provide ideal winter cover for deer. The sn accumulation is often only a third of the depth outside; and, if plantation is sufficiently wide, wind is reduced to a point where interior is almost still.

During the winter of 1954-55, an intensive study was made a 30-acre pine plantation, 40 to 50 feet tall, in the Varna area. F deer used this and the several small plantings in its vicinity as co Here they bedded down, and on stormy days they always retired to most protected parts. Only on warm sunny days did they bed do for afternoon rests in aspen or other hardwood cover. Observati during the following winter demonstrated the same pattern of use deer.

During the winter of 1955-56, deep snows forced the deer on study areas, except those on the northeastern portion of Connecti Hill, to yard. One such yard, consisting of approximately 104 de was concentrated on Turkey Hill (near Ithaca) where most of t plantings were in the 12- to 15-foot class. The plantings were utili very little, primarily because of poor cover and impediment of mo ments by low limbs and by deep snow between the rows. In this a deer beds were concentrated in the older, natural white pine stan Beds outside these stands were usually located under bushy, wid spaced white pines on slopes with southern exposures. A red p plantation, also sloping to the south, was used to a limited extent

A group of at least five deer remained throughout the winter the northeastern portions of Connecticut Hill which bordered fa land and included old apple orchards, aspen thickets and unharvest

n. Here again deer showed a preference for pines. All the deer s observed were located in the small pine plantings and none was overed in the hardwoods or hardwood-hemlock forest.

In the early part of winter 1955-56 the deer on the State reforesta- areas remained about the red pine and Scotch pine plantations ixed plantations containing those species. Beds in mixed plantings located under red pines, although deer trails crossed and recrossed entire area. By late January, deep snow forced the deer to the r valleys close to farm land where they yarded.

Scotch pine served a dual function for deer since it provided both and cover. Scotch pine tops in a plantation on Tompkins Area 3 were broken down by ice and heavy snow in 1954-55. Deer heavily on the terminal whorls of needles rather than on white r growing in an adjoining plantation. During the winter of 5-56 the deer in Section K of Connecticut Hill fed on Scotch pine. te pines and red pines were hardly touched.

The choice by deer of the terminal whorls of Scotch pine needles indicate a high nutrient content of these needles. It is a rather -known fact that deer tend to select the most nutritious forage dable (Swift, 1948). Leyton and Armson (1955) who studied the ral composition of Scotch pine foliage found a significant linear ionship between height and nutrient concentration in the needles. ent needles of the uppermost shoots were higher in nitrogen, ssium, potash and calcium than those of the lower branches. This explain the extensive feeding observed on the broken tops of ch pine.

Jack pine, because of its open and shallow crown, intercepts a small amount of snow. The depth of snow in the interior of a tation is very nearly the same as that in hardwood forests. As a lt the deer on Connecticut Hill and the State reforestation areas doned jack pine plantations when snow began to accumulate in n. Ruffed grouse also made little use of jack pine in winter, bly because of the light overhead and open crown which provided poor roosting cover. On Connecticut Hill, grouse wintered mainly d pine and Scotch pine plantations.

Rabbits on the study areas were generally most abundant in those plantations from 6 to 15 feet tall. At this stage the trees had not d sufficiently to shade out other vegetation. Food plants, especially ble and sumac, were still present, and the pine branches were enough to furnish good protection from snow, wind and predators o supply some food.

Beyond a height of 15 feet pines decreased in value for rabb In such situations these animals restricted their activity chiefly openings and edges where trees on the outside still maintained th lower branches. Tracks indicated that rabbits were using small blo of plantations as travel lanes from one food plot to another. T amount of rabbit use of the interior of plantations of taller pines seem to be influenced by the presence of old woodchuck *(Marmota mon* burrows. Often such burrows from 50 to 100 feet within a plantat would be occupied by rabbits even though the rabbits had to leave plantation in order to reach a source of food.

Plantations over 40 feet in height received only incidental by rabbits. On the Varna area, rabbit sign was common in the g dogwood *(Cornus racemosa)*, alder *(Alnus incana)*, hawthorn *(C taegus* sp.*)*, and aspen *(Populus tremuloides)* growth about the plan tion. The only indication noted of rabbits using the plantation it was the occasional wandering of a few individuals several yards insi

Though plantations are usually regarded primarily as winter co they seem equally useful to wildlife in summer.

Well-used deer trails and fresh droppings were common in ma plantations throughout the summer. Does seemed to recognize plan tions as secure places in which to conceal their young. Young fav and does with fawns were discovered in plantations on Connecti Hill and on the State reforestation areas.

Figure 6. Interior of a jack pine plantation. The ground cover is relati heavy.

Jack pine, deserted in winter, became a center of deer activity
ummer. The reason for the change may have been associated with
rgrowth. The jack pine permitted sufficient light to filter through
rown to encourage undergrowth (Figure 6). Herbaceous plants,
ially goldenrod *(Solidago* spp.*)*, aster *(Aster* spp.*)*, sedge *(Carex*
) and poverty grass *(Danthonia spicata)*, as well as saplings of
ash *(Fraxinus americana)*, red maple *(Acer rubrum)* and haw-
, were present in varying quantities. During the summer months
leer browsed heavily on maple, ash and aster in jack pine planta-
.

Ruffed grouse also made use of pine plantings during the spring
summer months. In 1955 grouse were flushed regularly in jack
plantations both on the State reforestation areas and on Connecti-
Hill. A grouse nested in the vicinity of a large grass and shrub
ing in a red pine-Scotch pine plantation on Tompkins Area No. 4.
ouse nest containing eight eggs was found on June 10, 1955 in
pening in the Varna red pine plantation. In 1956 on Tompkins
No. 3 a grouse brood was discovered in a jack pine plantation.

THE SPRUCE-FIR GROUP Winter conditions in spruces, balsam
Douglas fir are quite different from those in the pines. The
ontal branches intercept more snow, but once any weight has
nulated the load slides off. By late winter, the first five or six
of lower branches may be buried under 3 to 4 feet of snow
ure 7). Large drifts of snow accumulate between the rows, while
lt-like shelter with the ground virtually free of snow develops
ith the trees. In plantations where survival is 70 per cent or
nd numerous gaps occur, such winter conditions persist for some

uch accumulation of snow between the rows severely limited
travel on the study areas. As a result, plantations of spruce as
s pine, under 15 feet tall, were not used by deer in winter. This
ance of spruce by deer was illustrated by observations from the
y white spruce plantation. Well-worn deer trails were common
the edges of the plantation in winter, but the deer confined
elves to the adjoining mixed conifer-hardwood forest and a
w strip of red pine.

Winter rabbit populations were concentrated in plantations of
spruce and in those containing some spruce. Here they stayed
e pockets beneath the trees. The use of spruce as contrasted
pine was especially marked in the small block plantings on

Figure 7. Spruce trees in winter with limbs pinned down by more tha feet of snow, creating tent-like cover beneath them.

Connecticut Hill and on the State reforestation area. A typical co in a pine plantation would yield six to eight rabbit trails cente about small openings, while a count in an open Norway spr plantation would yield from 15 to 20 trails. A similar situat existed on a tract where red pine, white spruce and locust plantati were in close proximity. The rabbits concentrated in the spruce locust units and used the red pine only for travel lanes from spruce planting to another.

Spruce was ideal for grouse because of the same conditions wh made it so favorable for rabbits and unfavorable for deer. This evident on the State reforestation area where grouse had access to dif ent conifers within a relatively small radius. Only two out of five p plantations contained some grouse, while four out of five spr plantations and five out of six mixed plantations containing spr held grouse.

With the coming of spring, the deer returned to the spruce plan tions. During the heat of the day several deer were usually flus from the dense spruce growth of the Danby plantation. Here t fed considerably on white ash and sweetfern *(Myrica peregrina)* gr ing in the openings. A Douglas fir-Norway spruce plantation Tompkins Area No. 4 showed the same use pattern. Adjacent t natural beech-maple woods which formed the nucleus of the summ habitat, this plantation was used extensively in the summer.

ded more concealing cover than the relatively open hardwoods. ar examples could be cited for nearly all of the mixed plantations e study areas. Rarely would a visit to these plantings fail to some sign of deer activity.

Grouse were found in the Danby white spruce plantation during ummers of 1955 and 1956. Two birds were flushed regularly spruce-aspen and spruce-sweetfern openings and on several ons as many as nine dusting areas were found in one day in mid-er. In 1956 a grouse brood was discovered in a red pine-white -locust plantation on Tompkins Area No. 3. This brood was at lge between a strip of locust and a stand of Norway spruce. A f 10 recently hatched eggs was found 250 feet in from the edge mixed pine-spruce-locust plantation. The nest was at the base of pine near the edge of a 20-foot opening. On June 24, 1956 a brood was located 30 feet in from the edge of a spruce-pine- plantation.

With the coming of fall grouse began to appear more commonly plantation edges, where they fed on chokecherries *(Prunus iana)*, blackberries *(Rubus* spp.*)* and other fruits. All fall grouse on Connecticut Hill were made in the shrubby edges of tions. On Tompkins Area No. 4 ruffed grouse occurred in oods and jack pine in summer, but in late September they l into larch and spruce plantations. As winter came, grouse l into the adjacent Scotch pine and spruce plantations although rch was used as feeding areas. On Tompkins Area No. 3 grouse ied the hardwood forest and the Douglas fir-Norway spruce tions, but by midwinter the population had shifted to the large ed pine-Norway spruce plantation.

The use of plantations in summer by rabbits was difficult to ine. Since no trapping was done, few data were obtained. No s were observed in the plantations during the summer although were seen occasionally along the edges, fire lanes and in the gs. Since the home range of a female rabbit varies from 3 to es (Dalke and Sime, 1938; Haugen, 1942) rabbits occupying ntation in winter probably leave to raise their young in the nding grass, overgrown fields, and openings.

pruce plantings are valuable in creating favorable habitat for oe hares *(Lepus americanus)*. During July 1954 hares were l in spruce plantations on the Bear Spring Mountain Game gement Area in Delaware County. Other large plantings in this also supported populations of this species.

Larch The larch has a longer period of height growth th any other conifer and its diameter growth is very rapid in youth. a result, larch plantations are much taller than those of oth conifers of comparable age. Larch, however, being deciduous, offe little winter cover; in fact, it offers less than a pure hardwood fore Heavy snows pin down the pendulous branches which hold up t snowfall to abnormal depths, a condition which does not exist pruned plantations. Ruffed grouse were found consistently in win in one of the larch plantations under observation. Sign indicated th they were only feeding there, especially in the hedgerows cutti through the planting, and that they were roosting in an adjacent Sco pine plantation.

In summer the relatively thin crown of the larch favors a grow of moss, bramble and mixed herbaceous plants underneath. This especially true if the plantation has been thinned. The larch plan tion on Tompkins Area No. 3 contained several well-worn deer trai fresh droppings were common and there was considerable browsi on the undergrowth. In August of 1954, 1955 and 1956 grouse mov into this larch planting. Intensive surveys revealed no use of larch grouse during the spring and early summer.

White Cedar White cedar plantations offered relatively po cover even in good stands and only limited use as deer browse w observed. Deer preferred pine to a well-stocked cedar plantation the Varna area. The cedar there and on the State reforestation are showed little browsing past or present; but on Turkey Hill a poor stocked plantation was nearly destroyed during the winter of 1955-5

Other Influences

The distribution and abundance of wildlife in plantations is oft determined by conditions more or less independent of the particul coniferous species involved. Among these are the area of the plantin the site, the nature of the edges, the presence, size and abundance openings, and the management practices applied to the plantation.

Area of Plantation The use of small plantings (i.e., und 5 acres) in summer and winter appeared to be dependent largely up adjacent cover. Plantings located next to woodland on Connecti Hill were used to some extent by grouse and deer. Others in old-fie situations were used for cover by grouse in fall and winter; the plantings were close to a food source of the grouse. Isolated plantin

pen fields were utilized by rabbits until trees reached a height of ut 20 feet. After this the plantings, particularly pines, appeared to of little use to wildlife, including passerine birds, in summer and e of limited value in winter. They, of all plantations, most closely roached the "wildlife desert".

Small plantings situated close to one another received more use by in winter than solitary plantings. Deer trails on Connecticut Hill cated that deer moved from plantation to plantation while crossing area and that they bedded down in several of them. The beds in e plantings were usually located 15 to 20 feet inside.

Cottontail rabbits benefit the most from small plantings. On key Hill various conifers had been planted in small blocks approxiely 200 feet square. The surrounding areas were rich in food ts such as sumac *(Rhus typhina)*, gray dogwood, brambles, black st and grass. Here rabbits were everywhere, and in winter the was covered with a maze of tracks leading in all directions. A lar situation existed on Connecticut Hill, although the plantations e beginning to pass out of usefulness for cottontails because of the uration of the pines. In the mixed and spruce plantations on apkins Area No. 3 where the food supply in the openings was ewhat similar to that of the Turkey Hill and Connecticut Hill s, rabbits were common only about the edges and in the openings. probable that on Turkey Hill and Connecticut Hill, where the tings were small and well distributed, the rabbit population per was much larger. Furthermore, observations on portions of Conicut Hill, where conifer survival was poor and the trees widely ed and where small clumps of conifers had been established, cated that such conditions are quite attractive to cottontail rabbits.

Openings The amount of vegetation in the openings inced wildlife use. The Danby white spruce plantation provided an llent example since it had a number of openings, some grown to plants, others almost barren of vegetation. Rabbits were common penings growing to sumac, on which they fed heavily in winter; rabbit sign was absent in those where the soil was too thin to port much plant life. Grouse utilized these openings with thin cover exposed mineral soil for dusting (Figure 8) ; but usually they were ed in aspen openings. In late summer, fall and early winter sign was found only in those openings grown to sweetfern and r woody vegetation on which the animals browsed.

Openings from one-quarter to 2 acres were used rather exten-

Figure 8. An opening on thin soil supports little plant growth, but pro
dusting areas for ruffed grouse.

sively, especially if they contained grass, bramble and other vegeta
(Figure 9). Deer, particularly does and fawns, used the meadow
openings in summer and fall. Cottontail rabbits occupied these l
openings permanently, particularly if some sort of usable bur
existed.

Locust lanes Rabbits and grouse were more common
plantations containing narrow blocks of black locust than in mos
the other large plantations (Figure 10). The locust lanes prov
openings at regular intervals. More important, the nitrogen-fi
properties of the locust stimulated a dense growth of grass
brambles. This furnished excellent food and cover areas for rab

Figure 9. A bramble opening in a larch-pine-spruce plantation.

gure 10. A locust lane in early spring. Such areas support a heavy herbaceous growth in summer.

ouse and deer. Ike (1957) compared the nitrogen content of the nual and biennial growth under locust and in old fields in two mple tracts in the same general areas as the plantations under study. nder locust the vegetation, chiefly bramble, had a mean content of .55 pounds of nitrogen per acre on one sample and 25.55 pounds r acre on the other. The old-field samples, principally poverty grass

and goldenrod, had means of 19.10 and 12.50 pounds per a respectively. Thus a considerable difference existed in the qualit food produced under the two conditions.

Pruning and thinning Once a plantation has been pru and thinned, changes take place which greatly affect the wil population. Under plantation management for timber produc pruning and thinning are usually begun when trees are not more 15 to 20 feet tall. This is the very stage when they are becoming valuable for wildlife. In New York, practices vary from crop pruning and thinning to complete pruning and removing every t row of trees.

Pruning and thinning several plantations, mostly pine, was un taken in 1955 and 1956 on Connecticut Hill by State game man ment personnel. This operation involved pruning every tree, ex for the four to six outside rows, removing the poorer conifers completely eliminating volunteer hardwoods. The plantations opened to such a degree that they were of little cover value to de summer and winter. In 1954 and 1955 a doe used a small pine pla tion to conceal her fawn, as well as to bed. In 1956, after the pla tion was pruned, no deer used the planting. Another plantation pr and thinned in a similar manner was still utilized by deer, but for feeding on red maple cut in the process.

This type of pruning operation appeared to be detrimental ra than useful to wildlife. Such thinning operations are too light to the overhead crown sufficiently to encourage undergrowth; hardw growth coming into the plantation is removed; and the under is opened to the point that the plantation no longer affords s cover. Observations seem to indicate that, for wildlife cover, plete pruning should be avoided and thinning practiced in accord with wildlife needs.

Scotch pine, jack pine and larch plantations, however, are ably improved for wildlife by thinning. The crown growth of jack and larch is open enough to permit moderate ground cover to before thinning. Thinning would increase the amount of light r ing the ground, encouraging growth of herbaceous plants, bra and tolerant hardwoods. Brambles are a characteristic compone the understory of thinned larch plantations here and in Europe. presence of a good understory would favor the use of such planta by small mammals, grouse and deer.

Cover value is not the only characteristic of a plantation v

ly be affected by pruning and thinning. Changes in the micro-
nate also result (Kwoh-Hwa, 1946). The effect of thinning on the
croclimate of the area may have some influence on animal use.
is was observed in the case of deer use of the Varna pine plantation
January and February 1956.

From mid-January through late February this plantation was
ited daily regardless of weather. During stormy weather and in
d periods the deer bedded in the unmanaged portion of the planta-
n although the snow was deep there. The reason for the choice of
unmanaged portion apparently was concealment and protection
m the wind. This part of the plantation was farthest from the
e and even on the stormiest days there was little wind. In the
naged portion the wind still mantained some force. As the weather
derated in mid-February, the snow left the managed area much
re rapidly than the rest of the plantation. The wind was warmer,
ground was free of snow and the sun was warming the surface
the south-facing edge of the plantation. When these conditions
ne about, the deer began to use the thinned area more and more
bedding.

anaging Plantations for Wildlife

Many plantations could support higher populations of wildlife
n they do now. Observations made in plantations as they existed
the time of survey suggested management practices that might
rease their wildlife potential. The following comments are made
marily from the viewpoint of improving habitat conditions for
dlife. Nevertheless, it is felt that management for game can be
egrated with good forestry practices.

The size of a plantation to be established should be based on the
d of wildlife desired. Where large acreages of open land exist, large
ntations are not out of order, if a variety of openings are provided.
e past policy on State reforestation areas of leaving unplanted strips
chain (66 feet) wide on either side of hedgerows was effective in
proving wildlife conditions. A number of other openings occurred
ually because of variations in the topography or soil types in the
a. However, it would be well to leave certain parts unplanted if
y are already valuable to wildlife or could be further improved
nearby cover. This includes wet spots, heavy growth of brambles,
nac, hawthorn, dogwood, old orchards and hedgerows. The influ-
e of openings on the variety and distribution of wildlife attracted
the plantations demonstrates their value.

When large areas are to be planted the pattern of refores could be modified to form a sort of checkerboard arrangement, blocks of conifers of several species alternating with unplanted These unplanted areas do not need to be the same size as the c blocks. Unless allowances are made for openings, an area will pr only a small amount of wildlife.

Openings must produce food for game in order to serve thei pose. In some instances this will necessitate planting them to s such as multiflora rose *(Rosa multiflora)*, silky dogwood *(C amomum)* and Tartarian honeysuckle *(Lonicera tartarica)*. openings must be maintained, since they are subject to successi are all abandoned areas. The plant composition could be cont by cutting and chemical means.

Areas of black locust are particularly desirable in conifer p tions, wherever they have a reasonable chance of development, irr tive of their timber value. The locust might be planted eith blocks within a plantation or in narrow lanes from six to ten wide through it. Locust itself is of little direct value to wildlif its nitrogen-fixing property provides an indirect means of sus nitrogen fertilization. This encourages a heavy herbaceous g cover which not only provides summer cover for grouse brood also a food source relatively rich in nitrogen for rabbits and d

Fire lanes as they now exist may have lost much of their val fire protection, but they are important to wildlife in a large plan (Figure 11). They increase the amount of edge in large areas, p dusting places for grouse, summer food and cover for rabbit food and summer travel lanes for deer. This is true where fire are not disked annually and when vegetation is allowed to deve

Fire lanes could be improved for wildlife and still retain as fire lanes. One possibility is the use of birdsfoot trefoil *corniculatus)* as a cover plant to provide summer food in the fo forage and grassland insects. Such treatment would require see preparation, liming, fertilization and fall cutting to elimina hazard of dry grass in the spring and to maintain the stand. T and management of such cover would eliminate the need for c and harrowing, and would eliminate or reduce invasion by plants. Such practices cannot be advocated, however, before economics in relation to wildlife produced are investigated.

Although observations on the use of small ponds and mars plantations were limited, it appeared that water areas do ad siderably to the value of a plantation for wildlife. A small p

are 11. A fire lane in a larch-pine-spruce plantation. Such lanes increase the amount of edge and provide travel lanes as well as feeding and dusting areas.

midst of several small plantings on Connecticut Hill was used deer until is was frozen over in winter. Rabbit and raccoon *(Procyon or)* were observed about its banks. In Allegany County (N. Y.) nds and marshes have been established in larger plantations, and se have increased the wildlife values of their areas. Deer con- ently used the ponds as sources of water. Raccoon came into the ntations. On many, mallards *(Anas platyrhynchos)*, black ducks *nas rubripes)*, wood ducks *(Aix sponsa)*, green herons *(Butorides escens)* and spotted sandpipers *(Actitis macularia)* were observed. properly placed in respect to fire trails and topography, these ponds ld be valuable for fire-fighting purposes, thus serving both the needs wildlife and forestry. Such ponds can be constructed at moderate t in low, wet areas not suitable for planting trees.

Small plantings will be most useful if planted close to some acent cover such as hedgerows, woods or overgrown fields. Plantings m 1 to 5 acres in area, placed close to one another and separated by lges, brushy areas or hardwoods are used more by rabbits, grouse deer than are isolated small plantings.

Mixed plantings are more desirable from a wildlife standpoint n pure plantings of any one kind of conifer, since they add variety the habitat. Where site conditions permit, plantings should consist two or three types of conifers. Each type should make up a fairly le band or block, with a minimum of 20 rows of pine and 10 widely

spaced rows of spruce-like trees. This would prevent any one from becoming dominant over the other and crowding it out of e ence. The blocks would be wide enough to create the condi characteristically associated with the types of trees involved.

In planting any area, large or small, to pine, the plantation sh be surrounded by several rows of spruce (Figure 12). After a plantation grows beyond 20 feet tall, its edge conditions deterio Spruces produce better cover conditions about the edge and re the flow of wind into the interior.

Figure 12. Outside rows of spruce create better cover along the edg reduce the penetration of wind into the interior of a pine p tion.

Various conifer species should be used in establishing planta since wildlife benefits from variety. Jack pine and Scotch pine sl not be overlooked. Jack pine can adapt itself to such adverse c tions as drought, thin infertile soils, and intensely cold winters open crown permits an understory to develop, an important fact the summer use of plantations. Although its short life span wil permit it to become a permanent part of any wildlife habitat, it aid hardwood forest succession on abandoned land by serving nurse crop for black cherry, white ash and others. It is espe valuable for controlling accelerated erosion and revegetating banks. Its susceptibility to breakdown by snow creates very favo environments for grouse and rabbits within the stand. Scotch like jack pine, is adaptable to dry, sandy soils and is susceptal snow damage, creating openings and brushy conditions favoral small game. Once a Scotch pine planting is thinned, an unde

sh and maple appears to develop very rapidly, in sharp contrast onditions associated with red pine.

Plantations are dynamic. They are growing continually, and with growth changes occur which affect their use by wildlife. Pruning thinning further influence the character of a plantation. While vth may be difficult to regulate, practices can be applied to main- the best conditions for the longest period.

If the trees are spaced 10 by 10 feet rather than 6 by 6 feet, the bility of a planting for cottontail rabbits, snowshoe hares and se could be maintained for a longer period. This would permit pines to retain their lower branches and the herbaceous plants to ain for a longer time. In most of the plantations studied, large or ll, rabbits made the most use of widely spaced, bushy conifers. ted observations also indicated that the same was true for pheas-

The same wide spacing is recommended for spruce, especially if area is to be attractive to grouse and snowshoe hares. Six by six- spacing of spruce is satisfactory if trees are periodically removed Christmas trees. On the Bear Spring Mountain Game Management , spruce plantings were maintained in excellent condition for se and hares by this practice. The trees, 25 to 30 feet tall, were inally spaced 6 by 6 feet; but removal of Christmas trees permitted remaining spruces to retain their lower branches and brambles evelop among them.

An interspersion of stands of uneven heights is preferable to a orm plantation, especially for rabbits and grouse, because of the ter number of edges and the better ground cover produced. Stands neven heights can be developed in several ways. One method is nclude rows of fast-growing conifers, such as larch, with slower- ving species. On larger areas the plantings could be staggered over or three planting periods about five years apart.

Management of plantations for Christmas tree production is one ne best ways to develop uneven stands. It would work well in all jack pine and larch plantations. If the trees cut were replaced planting new seedlings, an uneven stand would result. The height ld range from 2 to 12 feet or more, and all trees would be bushy branches close to the ground. These conditions would be stabilized a comparatively long period of time. Such plantations would te excellent conditions for rabbits and, to a certain extent, for se. On beagle trial grounds, where optimum cover conditions for

cottontails must be maintained for a number of years, manag of plantations for Christmas trees is recommended.

To benefit wildlife, pruning and thinning in red pine and s plantations should be restricted to crop trees, and the outer f six rows should not be touched. Jack pine, Scotch pine and plantations may often be made more desirable wildlife habitats by intensive pruning and thinning. This would permit developm a dense understory. Thinning in spruce plantations should be to allow as many trees as possible to retain their lower branches w suffering from competition from surrounding trees. Crop tree should have their lower branches removed.

Although hardwood growth in plantations is regarded in cases as poor management by foresters, the presence of some hard is of great value in maintaining an abundance and diversity of life. This fact has also been observed in Europe (Mackenzie, Where wildlife values are to be given priority, aspen thickets, thorn, wild cherry, sumac, and other trees should be allowed to and even be encouraged in as many places as possible. The impo of these hardwoods in the distribution of grouse, rabbits, and throughout a plantation cannot be overemphasized. Hardwoods be cut only when it will result in increasing more valuable g cover or when sprout growth is desired.

Application of these management practices to reforestation can materially improve the conifer plantations as wildlife habi the actual needs of wildlife are considered when the plantation is planned and planted, then no conifer plantation needs to be a v desert.

DISCUSSION

This study underscores the facts that plantations can suppor life populations and that more study is needed on plantation-v relationships. The work was necessarily quite broad in its appro order to lay the groundwork for more intensive studies, which, if should extend over several seasons within individual plantation

A study of this sort has been reported by Bailey (1958) studied, by means of line transects, the occurrence and penetra grouse in a 265-acre stand of various conifers in the 20-year ag His results support the data obtained by the author. Ruffed seldom used the interior of solid red pine and white pine stand the presence of scattered openings, apple trees, and brushy hed within the stands greatly influenced their use by grouse. Other

portance in the utilization of these plantings were the cover types ent to the plantation.

The results of the present study and the data being obtained from ntensive study by Bailey indicate that plantations cannot be written s biological deserts. The biological desert concept, so firmly ched in the thinking of many wildlife biologists, can be traced to the work of Edminster (1935). Unfortunately his study has nly been misinterpreted but also used as a basis for sweeping and rranted generalizations concerning the wildlife values of planta-

The fact not considered is that the plantings were entirely pine, were solid with all breaks being replanted. The results obtained dminster are still valid as long as they apply to plantings 25 to 30 n height with negligible breaks in the canopy. His data, although ive, strongly support the premise of this study that, if appreciable s in the canopy and other diversity in the cover occur within lantation, then these areas will usually support huntable wildlife. plantation is solid and is composed of one species of conifer , then the abundance and diveristy of wildlife will decrease as ea of the plantation increases.

At times the statement is made that plantations do not support ich wildlife as native forests. In these instances the fact is for- that reforested areas are for the most part abandoned agricul- land. Differences exist between undisturbed forest soil and the f lands that have been cultivated and abandoned, even though nt. Stewart (1933) found that the fertility of the soil was much once a forest was cleared, the land cultivated, and then left ert to a poverty-grass sod or to moss and ferns. This change d in a loss of permeability, smaller water-holding capacity and air spaces. The forest soil had a deeper A and B horizon and preciably larger content of total nitrogen and total carbon than djacent poor pasture. Poor pastures in many cases had a con- ble content of unavailable nitrogen and carbon from unde- sed residues, which accumulated in a compact mat. Thus the pes of site are quite different in soil characteristics and fertility. influences plant growth, the nutritional quality of the available , and, in turn, the relative value of such areas to wildlife.

The plantation and the native forest represent two different suc- al stages, developing under different environmental conditions. has been recently created artificially, while the other has been ping and probably present for many years. The more valid

comparison is between the plantation and the surrounding unpl fields which were abandoned at the same time as the planted ar

When large plantations are examined from this viewpoint, is no doubt that they have created favorable habitat for certain s of wildlife where poor habitat existed before. Likewise, pla destroyed habitat for other species. When one considers the surr ing cover and the stage of development in which the fields would be had they not been planted, one must conclude that pla abandoned hill lands has provided habitat for game that did not before and would not otherwise exist for years to come.

Deer, grouse, in some cases cottontail rabbits, and a vari passerine birds would not be present on the areas today had n open land been planted to trees. This does not imply that refores areas are ideal wildlife habitats. There is much room for improve especially in the availability of food. Survival failures, howev pine stands and cover interspersion provided by mixed stands c a habitat which developed in favor of many game and non- species.

The habitat is continually changing, whether it be the de ment of a plantation or succession on abandoned land. It through stages of low productivity to a maximum and declines t a minimum again. As a plantation passes out of its period of g usefulness, the surrounding area may be reaching a period of max wildlife values.

This fact requires that some additional thought be given to ing practices. It would be unwise to plant an area so comple evenaged conifers, even allowing for openings, that the entir would eventually pass out of productivity for wildlife. A vari conifer species must be used and uneven stands created. There be a balance between planted and unplanted lands. Areas, esp those close to seed sources, should be allowed to revert to naturally to supply habitat when the conifers have passed out o usefulness to the maximum number of game species.

CONCLUSIONS

This study points out several facts. First, it is difficult to gen about the wildlife values of conifer plantations; each planta individualistic. Second, the ultimate effect of a plantation on th life community depends on a great number of factors, includin coniferous species, height, size, openings and management. The p

lly has indicated some of these, and it has suggested that the proper nbination of management practices can create good wildlife habitat. Plantings of 1 to 5 acres in extent are of little value, especially hey are not adjacent to other good cover types or close to one ther, unless they are managed to maintain their height at 12 to 15 and to develop good ground cover. Plantations consisting of blocks everal types of conifers are more attractive than pure plantings of one species. The inclusion of lanes of black locust in a plantation rtly increases its value to wildlife. Plantations over 10 acres have ted favorable habitat for certain species of wildlife in areas where habitat for them existed before. In these, survival failures and r interspersion provided by mixed stands have been a major factor. diameter of large plantations is of little significance as long as tive openings occur within them. If, however, the planting is l and its canopy unbroken, then the wildlife use of the area nishes as its size increases. Management should be designed to te and maintain, insofar as compatible with other interests, the rsity of cover that is essential to productive wildlife environment.

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TOXICITY OF CYANIDE TO BROWN TROUT AND SMALLMOUTH BASS

G. E. Burdick — Senior Aquatic Biologist, New York State Conservation Department

Howard J. Dean — Aquatic Biologist, New York State Conservation Department

Earl J. Harris — Analytical Chemist, New York State Conservation Department

ABSTRACT

Toxicity curves for cyanide are established for brown trout and smallmouth at 60° and 70° F., respectively, through plotting mean time to death ..st concentration. A constant-flow, constant-temperature device was used he procedure and is described. A comparison is made between the toxicity vanide in a soft, acid water and that in a water of median alkalinity for State. Methods of reduction of oxygen are compared preliminary to estab- ag toxicity curves at reduced oxygen comparable to the "standards" estab- d by the Water Pollution Control Law of this State.

A threshold value for toxicity is approximated for each of these curves he graphical method previously described by the senior author, and the hod is used to compute the equation of the curve.

The discharge of cyanide-bearing industrial wastes into surface ers frequently results in the occurrence of fish kills in such loca- is. When the duration of exposure is too short to produce death, overy is rapid and apparently complete, with no traceable aftereffect, he fish are removed to water not containing this substance, or the harge ceases, permitting the water to clear. In the case of the ali cyanides, recovery has occasionally occurred after a fish was arently dead. This pattern of behavior suggests that a curve ting the time of exposure necessary to induce 50 per cent mortality he concentration would be of more value in predicting the effect specific discharges than the estimation of a single threshold value long-term exposure at relatively low concentration. Accurate mation of the toxicity of any highly toxic substance, such as cyanide, uires the availability of an accurate and reproducible analytical hod which can be used at extremely low concentration.

While some exploration of cyanide toxicity was recorded in the rature before such methods were available, most of the critical k is comparatively recent in origin. Karsten (1934) constructed elaborate constant-flow apparatus in which dropwise addition of nide was made to the flow from a constant-flow siphon. Neither temperature nor the oxygen concentration was reported, although

the complexity of the apparatus makes it appear likely that the perature approached that of the room. Since it was not possib measure the cyanide by the methods known and available at time, it was necessary for Karsten to assume some theoretical vari ity in concentration. He assumed a variability of not more tha per cent and believed it would generally be in the direction reduction in the cyanide content. Using the brook trout *(Salve fontinalis)* as a test animal, he reported that 0.02 p.p.m. of cya was non-lethal over a period of 650 hours, and that a concentra of 0.05 p.p.m. was certain to kill all trout within about 120 h It was suggested that 0.02 p.p.m. is the maximum which shoul permitted in any water if the usual species of trout are to be consid

Southgate, Pentelow and Bassindale (1932) reported data experimentation on the effect of cyanide on rainbow trout. The were presented in the form of a toxicity curve, with the concentra of cyanide in p.p.m. plotted against time. In a temperature r from 5° to 20° C., the reciprocal of the time for 50 per cent turn was found approximately proportional to the water temperature. increase in toxicity was found to be associated with a decrea the dissolved oxygen concentration.

Downing (1954), using a continuous-flow procedure, evalu the effect of variation in oxygen concentration on the survival tim rainbow trout at three different cyanide concentrations from 0.1 0.155 p.p.m. and presented these data in graphical form. This confirmed the conclusions of Southgate, Pentelow and Bassindale indicated proportional relationships. Loss of equilibrium, follo by a 5-second cessation of swimming movements, was taken as endpoint for establishing survival time. All controls were state have survived the period of exposure.

Herbert and Merkens (1952) described a constant-flow d which they used to determine a toxicity curve for cyanide, using bow trout at a temperature of 17.5±½° C. Previous to use, experimental fish were unfed and acclimatized to the experim temperature for a period of 48 hours. They conducted a single co experiment when their testing of the effect of the various cya concentrations was approximately half finished. No losses occu among the control fish during a period equal to the longest exp to a cyanide solution. Turn-over and cessation of swimming move for a period of 5 seconds was taken as a criterion in establishin ability to survive. The data were presented in tabular form, graphically as a curve. For the range in estimated cyanide co

tions from 0.25 to 0.07 p.p.m. (determined values indicate mean centrations from 0.22 to 0.0598 p.p.m.) the data have been fitted h a straight line, although they might equally as well be considered be curvilinear. Use of the straight line implies that there would be true threshold value and that cyanide would affect survival down zero concentration. The lowest concentration tested was 0.07 p.p.m. erage by determination 0.0598 p.p.m.). The mean survival time his level was 4,441 minutes. Variation in survival time was ascribed ndividual variation in the fish.

Wuhrmann and Woker (1953) tested the effect of temperature cyanide solutions on several species of fish, including brown trout. e oxygen concentrations were stated to be high enough to be with- influence. Their data show an increase in toxicity with increase in perature from 1.2° to 25.4° C. The cyanide content was variable, ging from 0.53 to 0.65 p.p.m., with a mean of about 0.572.

Herbert and Downing (1955) repeated a part of the 1952 study, g a different stock of rainbow trout and omitting temperature limatization. The comparison curves are essentially parallel, though placed in time. Length in relation to survival time is shown to be related in two of three comparisons. Consideration of their data s not clarify the exact cause of the time displacement, whether from s of acclimatization or from a population difference in whole or in t.

Little information is available on the toxicity of cyanide to small- uth bass. Renn (1955) presented data for largemouth bass and d smallmouth bass among the species used in his studies. The er species does not appear in his graphs and, in a personal com- nication, he stated that it was omitted in shortening the presenta- n. He supplied copies of the original figures and further commented t a limited number of experiments were run at low oxygen values out 4.0 p.p.m. at 22° C.). Under these specific conditions the llmouth bass appeared to be one of the most sensitive fishes. The er species reported in his paper were tested at somewhat higher gen concentrations. Renn used 100 per cent survival over 24 hours general criterion and noted any mortality occurring in this period. the smallmouth bass, no survival of this degree was obtained for solutions down to, and including, 0.061 p.p.m. of cyanide.

Studies on the toxicity of cyanide to brown trout were initiated he Rome Pollution Laboratory (N. Y.) in 1953 using static solu- s. Periodic replacement was used to re-establish the desired con- tration when analytical determination showed it to have been

significantly reduced. Due to the time required to conduct this det mination, no check and replacement was used for the higher conc trations. In general, there was no replacement with exposure tir of one-half hour or less. It had been noted in exploratory work th at low concentrations of cyanide, an apparent physiological adjustm took place which at times enabled a fish which had been turned o for a lengthy period of time to right itself and remain upright dur the remainder of the experimental period. Replacement of solut had little effect upon this phenomenon, so it did not appear to be to loss of cyanide from the solution. Use of the criterion of turn-o and cessation of swimming movements for 5 seconds which had b used by the British authors cited, was therefor rejected, and cessat of respiratory movement and failure to respond to irritation was u as indicative of death.

PROCEDURE

The studies carried on called for creating, and maintaining wit small tolerances, specific conditions of solution and temperature which to test experimental fish. It was necessary to design and assen apparatus that would meet these requirements. This equipment the way in which it was used are described here, together wit general summary of the statistical treatment of the data obtai Further details are given, as pertinent, under the accounts of experiments conducted.

General

A stock solution of potassium cyanide was made up and standa ized periodically by silver nitrate titration, initially by the Li method, but, in the latter part of the study, by the "standard meth of the American Public Health Association (1955). Measured volu of this solution were transferred and mixed with a measured vol of the experimental water calculated to provide the desired concen tion. Previous to the addition of fish, the concentration was chec by the procedure outlined by Aldridge (1945), or by a more sensi modification of this method which maintained the reagent propor stated by Aldridge to be necessary for the accurate estimation cyanide (Harris, E. J., this laboratory, unpublished).

Approximately constant temperature was obtained by immer the experimental jars of aquaria in an insulated, thermostatically trolled water bath, with variability generally less than $\pm 1/2^\circ$ F. temperature was recorded by a Negretti-Zambra recording thermom using a drum-type recorder on a chart covering 7 days. Data w

ed a fluctuation greater than $\pm\frac{1}{2}^{\circ}$ F. were discarded. All experi-
s were conducted below room temperature, control being achieved
termittent operation of heating coils to balance the entrance of
stant flow of cooler water.

Two natural waters were used in the course of these studies:
cid water of low alkalinity from Woodhull Creek, and a more
ine water with higher salts content from the Rome Hatchery
g. Complete analyses of these waters have been previously re-
d (Burdick *et al.*, 1954, 1955).

The oxygen content was uncontrolled at the start of the study,
his introduced so much variability that the data had to be sorted
oxygen ranges before use in comparison. Adjustment of the oxygen
nt to narrower limits was obtained by aeration of the experi-
al water at a constant temperature before the addition of cyanide
ts use as a test solution.

Hatchery fingerlings were acclimatized to temperature and the
nery springwater for a period of at least a week before use. Fish
unfed for 48 hours before use.

Chemical determinations were made prior to adding the fish,
periodically thereafter if the experiment was of sufficient duration.
ldition to cyanide, oxygen was determined by an iodized alkaline-
e sample-blank procedure modified from Ellis *et al.* (1946), or
ie straight Winkler procedure (American Public Health Associa-
1936) when this method was found to introduce no error. Carbon
de, methyl orange alkalinity, and pH were determined according
ocedures in the last reference.

Time of introduction, time of turn-over (loss of equilibrium)
time of death were noted for all fish, although turn-over is not
in any of the calculations presented in this paper. Except for
ds when failure to note the exact time for death would not
duce significant error (for example, in experiments of several
duration), the fish were under continuous observation as the time
eath approached.

Lengths of fish were recorded to the nearest millimeter, using
length. Weights were taken for some, but not all, fish although
ht is not used in the data reported in this paper.

Control experiments were used frequently, generally daily, in
xperimentation. No losses were recorded among the controls
eriods beyond the duration of the experiments for which they
d as controls. Further mention of the use of controls will not be
e.

Method and Procedure for Constant-Flow Studies

A low pressure system was used to force the solution contain the concentration to be tested from one, or a series, of 45-liter py bottles through a calibrated flowmeter. The metered flow passed the jar or aquarium in which the study was to be conducted. Con tion of possible increase of temperature in the flowmeter system, wh was exposed to room temperature, was made by passing the solu through a series of glass tubes immersed in the constant-tempera bath before entry to the experimental aquarium. The aquaria w covered by glass plates to prevent an air space and loss of cyanid the air-solution interface. Rate of flow was adjusted by mean a glass stopcock on the discharge side of the flowmeter. The sal features of this apparatus are diagrammed in Figure 1.

A rate of flow was used at which the loss of cyanide, or cha in oxygen concentration, due to the metabolic activities of the appeared to be at a minimum. Adequacy of flow was checked at ti by either doubling the flow or using only half the previous numbe fish. If no statistical difference was noted, it was assumed the rat flow was adequate.

The bottles containing the experimental solutions were imme in a thermostatically controlled constant-temperature bath simila that previously described for the experimental aquaria. Tempera was recorded by a 24-hour Taylor recording thermometer. The bo were clamped to prevent change of position as their contents w discharged.

A Marvel Model C aquarium pump was used as a source of pressure. This was actuated by a relay controlled from a merc filled, pressure-type switch, in which the mercury made contac approximately 3 pounds pressure, opening the contacts operating pump.

In some of the later, low-oxygen studies, low pressure was obta from a cylinder of compressed nitrogen controlled by a diaphra type control valve. With a high pressure airline, the use of su valve would insure accurate control of low pressure to opera similar apparatus.

Method for Obtaining Uniform Temperature and Oxygen C tent

The constant-flow procedure required large volumes of ex mental water intermittently to provide new solutions. Prepara

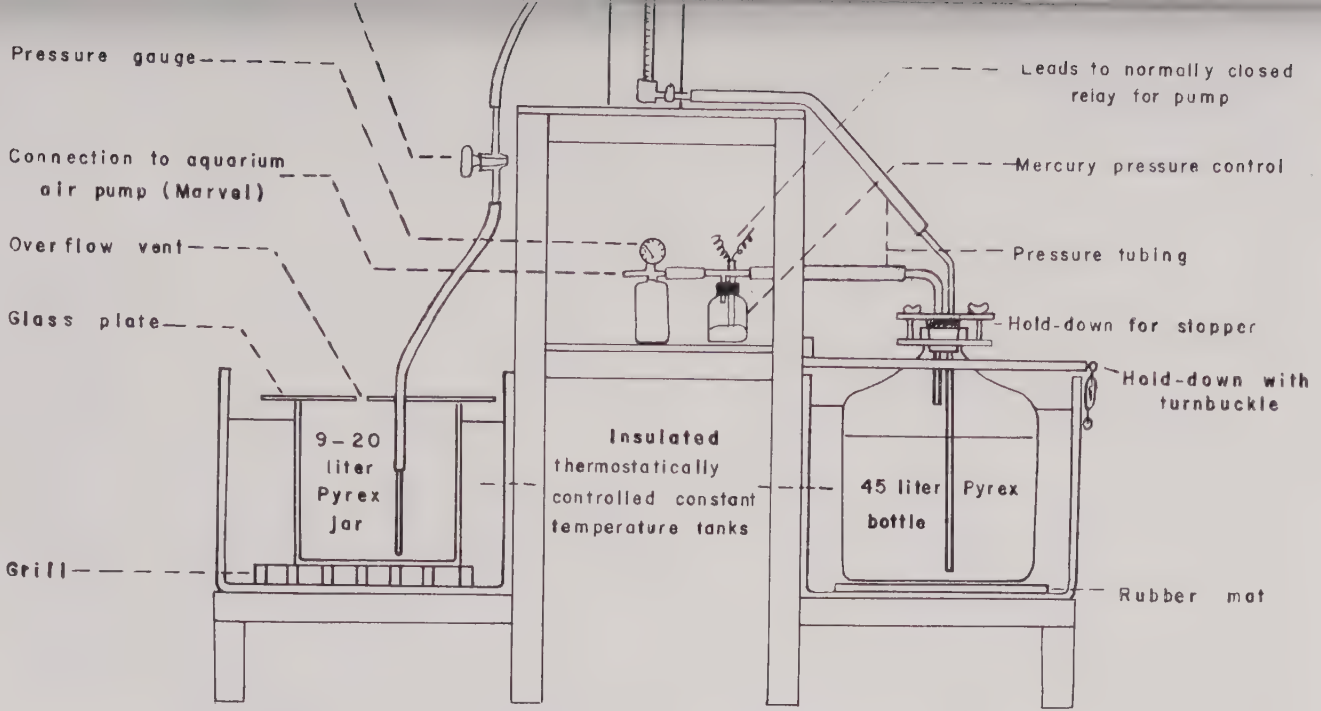


Figure 1. Diagram of constant-temperature, continuous-flow apparatus.

from freshly drawn springwater was found unsatisfactory, as it t
too long for the water to reach temperature and, unless the wa
was aerated for some time after reaching temperature, the oxygen
found too variable.

A 300-gallon aquarium was connected to the springwater li
so it could be refilled from that source. This was maintained at
experimental temperature by means of a thermostatically opera
solenoid valve that circulated colder water through helically coi
aluminum tubing placed in the aquarium and vented to the dr
Since the room temperature was higher than the experimental temp
ture, no source of heat was necessary, except when the tank had b
filled from the springwater line.

The helical coil was cross-connected to a valve from the hot wa
line. Circulation of hot water through the coil allowed adjustmen
the desired temperature quickly. To aid in stabilizating the oxy
content, the tank was maintained under continuous, vigorous aera
by diffuse air pressured from an aquarium pump. In use, wate
siphoned directly to the pressure jars.

Statistical Treatment

Time to death, expressed in minutes was found generally to fol
a logarithmic distribution, and the logarithmic mean is comput
and used in place of an arithmetic mean. When plotted aga
cyanide concentration on logarithmic paper, the antilog. of the m
log. of time appears to inscribe a smooth curve. This curvature
been ascribed to displacement on the axis of the graph (Burdick, 19
and graphical solutions have been used to estimate theoretical thresh
values and to calculate the equations for the curves which are give

Data are presented in tabular form throughout this paper
include mean length and range of lengths, range of time to de
mean time to death, and, since standard deviation and standard e
produce unequal results when expressed as antilogarithms, the
and minus deviations are combined as the spread of the statistic
thus also represent a range. "Student's" *t*-test (Snedecor, 1940)
been used for certain comparisons.

COMPARISON OF STATIC SOLUTION WITH REPLACEMEN AGAINST CONTINUOUS FLOW

The initial work with cyanide was based on a standing solu
which was replaced when analysis showed the concentration to

eased significantly. These data showed a rather wide range in to death. While such a condition might be inherent in the popun, continuing decrease of concentration during the period needed mplete the chemical analysis and prepare a new solution would uce a similar result. With the Aldridge method and its modificathis period would be in excess of 20 minutes and usually would ed 30 minutes.

In higher animals it has been demonstrated that, in detoxification, ide may be transformed to thiocyanate. If such a mechanism also s in fish and results in the excretion of some cyanide in this form, oxicity of the solution would be altered without a corresponding ge in the apparent cyanide content, since the procedure used termining cyanide does not differentiate between the two radicals. w concentrations, accurate differentiation is difficult and, although e seemed to be some evidence of the presence of some thiocyanate repeated use of a single solution with several batches of fish, it t believed to have, as yet, been definitely established.

An indirect check on the accuracy of the results in standing ions was devised by providing for comparison with those from a ared solution which was allowed to flow through a 7½-liter jar at ate of 10 liters per hour, providing a theoretical replacement of ion once every 45 minutes. At this rate of flow the cyanide was found to change significantly, and an increase of flow to 20 liters hour did not change the mean time to death appreciably. For procedures, Woodhull Creek water was used in the test solution the experimental fish were fingerling brown trout of the same .

The results from the two procedures are presented in Table 1, the range of time to death, the antilog. of the mean time to death, the standard deviation and standard error of the mean given as es.

The ranges of the times to death would indicate that the data ined from standing solutions are not as critical as those obtained ontinuous flow. While the concentrations were not exactly the , they were not too divergent except at the highest level recorded. out any correction of the means, all solutions tested significantly rent by "Student's" *t*-test.

Straight-line interpolation was used to correct the means to a non concentration and is also presented in Table 1. Since the ired correction was not large, it was assumed the pooled variance d be approximately the same and the *t*-test was again applied,

Table 1. Comparison of the Effect of Cyanide on Brown Trout in Static and Continous-flow Solutions of Woodhull Creek Water at 60° F. for Three Trials at Different Levels of Cyanide Concentration

Condition	Concentration (p.p.m.)	Number of fish	Mean length (millimeters)	Mean oxygen (p.p.m.)	Range of time to death (minutes)	Antilog. of mean log. of time to death (minutes)	Range of standard deviation of mean log. (minutes)	Range of standard error of mean log. (minutes)	Correction of mean by straight line graphical interpolation (to concentration of the other member)	Pooled variance (logarithmic)	Value of t
Flow*	1.06	20	44.7	10.4§	4.2— 15.2	6.58	5.1— 8.5	6.2— 7.0	8.32		
Static	0.96	30	42.2	9.8	6.0— 18.7	8.83	6.7—11.6	8.4— 9.3		0.01683	0.69
Flow*	0.51	20	41.4	9.8	8.5— 24	15.0	11.4—19.9	14.1—16.0	15.8		
Static	0.49	30	43.0	9.3	9.0— 47	18.7	12.5—27.9	17.3—20.1		0.01277	2.21
Flow*	0.32	20	41.2	9.4	17 — 48	30.1	23.3—38.8	28.4—31.9			
Static	0.31	30	47.6	10.2§	33 —230	74.6	48.4—116	68.9—80.7	67.8	0.02611	7.99

* Flow was at the rate of 10 liters per hour to a 7½-liter jar.

§ Single reading and not average.

the results shown in that table. It appeared to follow what t be expected in such a comparison if there had been a decrease ncentration with time in the static solutions.

The highest concentration would show the least effect, since would be little time for changes to occur. This comparison ed no significant difference in the results. The intermediate ntration showed significance between the 5 and 1 per cent levels, the lowest concentration, involving the longest time period, ed significance below the 1 per cent level. It was concluded that nuous flow would give the most accurate and reproducible results.

OMPARISON OF THE EFFECT OF WATERS OF DIFFERENT ALKALINITY AND pH

Two natural waters were used: (1) Woodhull Creek water with kalinity ranging from 6 to 12 p.p.m. and with a pH on the acid of neutrality; (2) Rome Hatchery springwater with an alkalinity ng slightly from 100 p.p.m. and a pH ranging from 7.5 to 8.28 e test solutions. Aeration of the Woodhull Creek water resulted ss of carbon dioxide and increase of pH. The pH was restored e original level by adding dilute hydrochloric acid before the ion of cyanide to form the test solution. Reference to the com- analysis of these waters has previously been made.

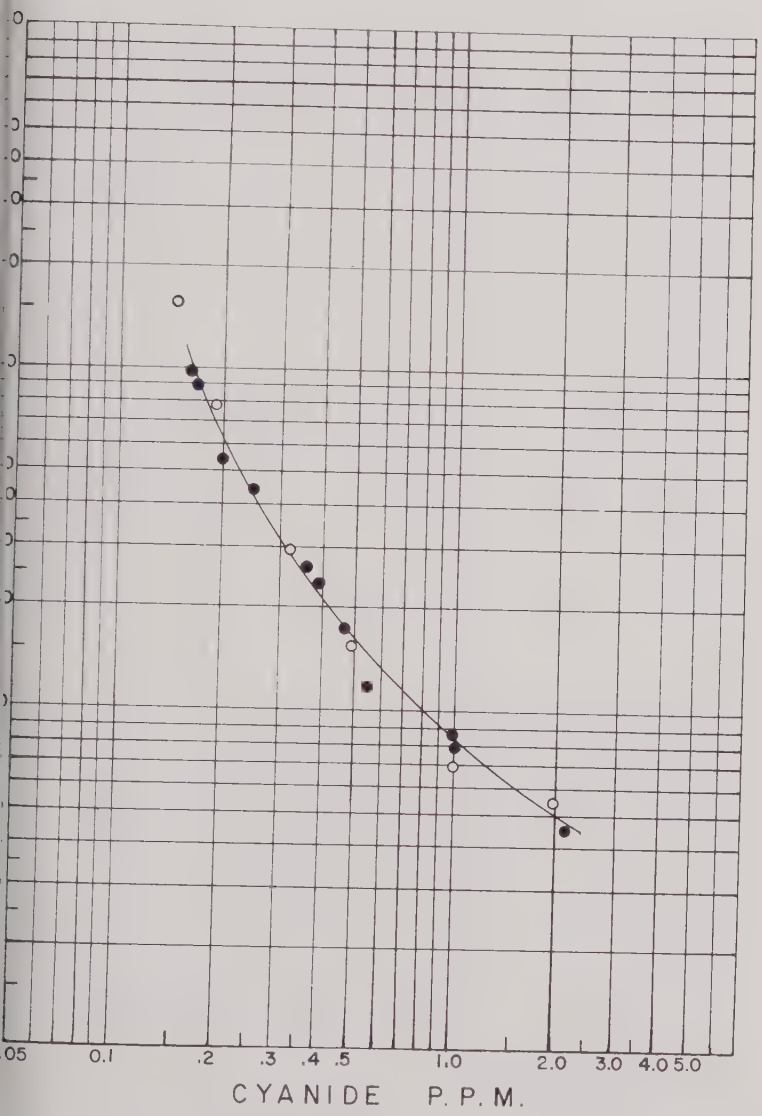
Comparison of these waters in static solution before the abandon- of that procedure had indicated little difference in the toxicity uivalent concentrations.

Using the same stock of fingerling brown trout from the Rome ery, a series of concentrations was tested in Woodhull Creek at a temperature of 60° F. The flow was at a rate of 10 liters our to a 7½-liter container. The logarithmic mean for time ath in each concentration was calculated and, with mean length, of length, oxygen content and its variation, pH and the ranges me to death, standard deviation and standard error, is presented ble 2.

The mean time to death is plotted against concentration in Figure a smooth curve is projected through these data. Another series ncentrations was then tested in the same manner, using the ery springwater, and the data appear in Table 2. The plotted s become superimposed on the curve previously constructed. position indicated that no significant difference developed from se of the two waters and it was concluded that further comparison nnecessary.

Table 2. Comparison of Cyanide Toxicity to Brown Trout in Water from Woodhull Creek and in Rome Hatchery Springwater at 60° F.*

Number of fish	Mean length (millimeters)	Range of lengths (millimeters)	Cyanide concentration (p.p.m.)	Mean oxygen concentration (p.p.m.)	Range of oxygen concentration (p.p.m.)	Mean pH	Range of pH	Range of time to death (minutes)	Antilog of mean log. of time to death (minutes)	Range of standard deviation of mean log. (minutes)	Range of standard error of mean log. (minutes)
					Woodhull Creek water§						
20	45.5	38 53	2.14	8.15	8.1 8.2	5.46	5.46 †	3.2— 7.0	4.5	3.6 5.6	4.3 5.7
20	43.6	37- 50	1.00	8.35	8.1 8.6	6.50	6.5 —6.5	4.8— 13.0	7.8	6.0— 10.2	7.3 8.3
20	43.6	34—52	0.98	8.55	8.4 8.7	6.49	6.49 †	5.5— 11.7	8.6	7.0— 10.5	8.2 9.0
20	46.2	33—56	0.55	8.60	8.6—8.6	6.03	5.7 —6.36	6.0— 24.2	11.6	7.9— 17.2	10.7— 12.7
20	43.5	35—49	0.47	8.25	8.2—8 3	6.48	6.44—6.51	8.0— 23.0	17.3	13.6— 22.0	16.4— 18.3
10	45.1	38—60	0.39	8.45	8.4—8.5	6.50	6.50 †	14.5— 48.0	23.5	16.2— 33.9	20.9— 26.4
20	42.3	33—55	0.36	8.40	8.2—8.6	6.30	6.29—6.30	13.5— 41.0	26.1	19.7— 35.2	24.5— 27.8
20	47.8	40—56	0.25	8.50	8.4 8.6	6.70	6.68—6.72	18.0—117.0	44.0	28.3— 68.3	39.6— 48.8
20	45.7	39 60	0.20	8.60	8.2—9.0	6.91	6.84—6.98	18.0—170.0	53.9	34.4 106.2	46.3 62.7
20	48.4	40—55	0.17	8.65	8.6—8.7	6.71	6.40—7.01	38.0—170.0	89.8	61.6- 134.1	82.1- 98.3
20	45.3	35—58	0.16	8.10	8.1 8.1	6.68	6.61—6.75	25.0—335.0	96.6	47.2—197.3	82.3—113.3
					Rome Hatchery springwater						
20	52.5	37—66	1.98	8.6	8.6—8.6	8.28	8.28 †	4.0— 8.5	5.5	4.4— 6.8	5.2— 5.7
20	54.5	39—68	1.00	8.3	8.2—8.4	8.00	8.00 †	5.3— 9.5	6.9	5.7- 8.3	6.6— 7.2
20	53.2	42—63	0.49	8.7	8.4—9.0	7.99	7.99 †	8.0— 25.0	15.3	10.6— 21.0	14.2— 16.4
20	54.6	39- 63	0.32	8.5	8.4 8.6	7.90	7.90 †	18.0— 47.0	29.3	21.5— 40.0	27.4— 31.4
20	55.8	40 68	0.19	8.55	8.5—8.6	7.50	7.50 †	35.0—263.9	77.5	43.3—138.7	68.1— 88.3
10	55.8	45 68	0.145	8.4	8.4 †	7.75	7.75 †	37.0—987.0	156.1	66.6 366.2	119.2—204.0



2. Comparison of the toxicity of cyanide to brown trout at 60° F. in two waters of different alkalinity and pH. Solid circles, Woodhull Creek water; open circles, Rome Hatchery springwater.

CITY OF CYANIDE AT OXYGEN LEVELS NEAR SATURATION

eterminations were made for brown trout, a cold-water species, r smallmouth bass, a warm-water species.

Brown Trout

The comparison of the toxicity in the two types of natural w had been conducted at an average oxygen level varying from 8.0 to p.p.m. This was considerably below the saturation level for 60°

Using fingerling fish from the Rome Hatchery, and with oxy contents more closely approximating the saturation value for 60° studies leading to the construction of a toxicity curve for such co tions were started in 1954. When the work was terminated bec of the approach of the field season, it was found that the gap betw 0.24 and 0.13 p.p.m. was too wide for proper delineation of this tion of the curve.

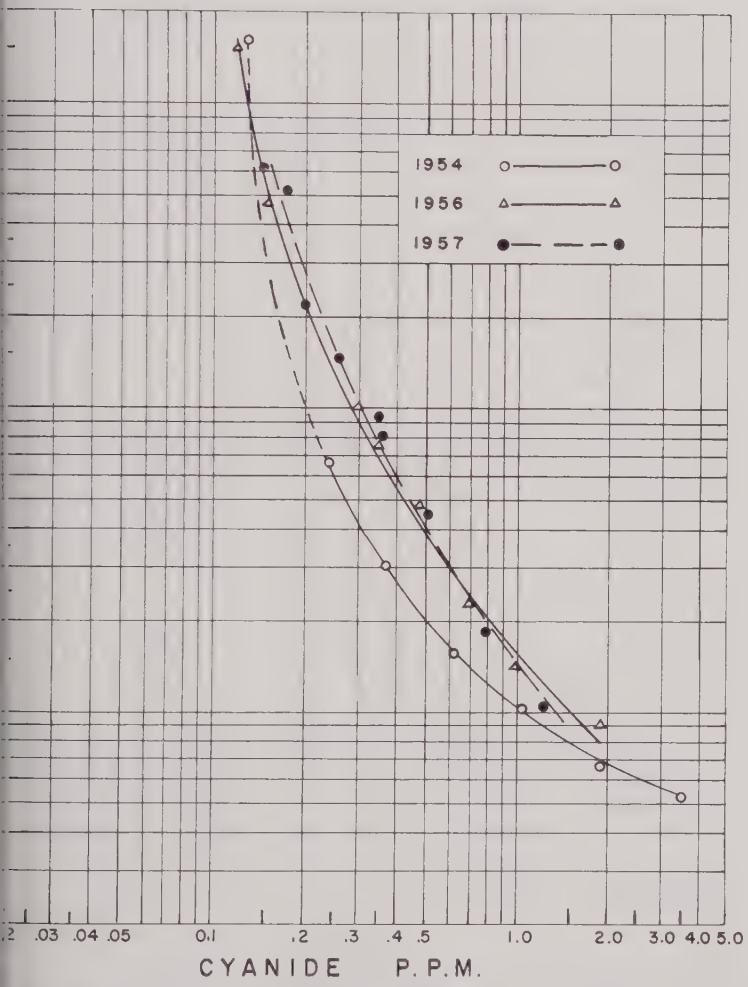
An attempt was made in 1956 to complete this gap in the cu using fish of the same approximate size and with all controllable fac essentially the same, but the data failed to fit the previous cu indicating a population difference in resistance to cyanide. I for a full curve similar to that of 1954 were then recorded u hatchery springwater and fish of the same approximate size f the Rome stock. The resulting curve, while somewhat parallel having a tendency to approach the same values at the lower con trations of cyanide, unquestionably indicated a population differ between the fish for the two years.

In terms of the average resistance of this species, no evalua of the curves in relation to this parameter could be made wit further repetition. In 1957, a stock of fish was obtained from Lake George Hatchery, which averaged about twice the size of t used in 1954 and 1956. The curve obtained through the use of t fish closely approximated the curve obtained in 1956.

The data for the three years appear in Table 3 and include range and average length for the fish, the range and mean of oxygen concentration, the mean (in minutes) and ranges for tim death, standard deviation and standard error, also expressed in min Records for the mean and the range of pH are incomplete, but t that were noted are given. There had been no indication that p these low concentrations had any particular effect on time to d so it was not considered important.

Plotting of time against concentration and construction of sm curves through the reference points, as shown in Figure 3, en comparison of the three curves with respect to time.

Some variability was noted in the plotted data and, althou appeared that the 1956 and 1957 data were not significantly diffe



3. Comparison of the toxicity of cyanide to three stocks of brown trout in Rome Hatchery springwater at 60° F.

of the variation could have been contributed by inclusion of a eak fish, or a few extremely resistant ones, in the small numbers in some of the concentrations. Determination of a logarithmic an, through eliminating the extremes of the data, would largely t for any tendency to error from this cause. A midmean for time th was computed for each of the concentrations listed in Table 3 dded to that table. The midmeans for 1956 and 1957 were

Table 3. Comparison of Three Stocks of Brown Trout in Resistance to Cyanide in Springwater at 60° F. with Oxygen at Near Saturation Levels

Number of fish*	Mean length (millimeters)	Range of lengths (millimeters)	Cyanide concentration (p.p.m.)	Mean oxygen concentration (p.p.m.)	Range of oxygen concentration (p.p.m.)	Mean pH	Range of pH	Range of time to death (minutes)	Antilog. of mean log. of time to death (minutes)	Range of standard deviation of mean log. (minutes)	Range of standard error of mean log. (minutes)	Midmean (central 80 per cent of data)
Rome Hatchery stock (1954)§												
20	45.4	38—53	3.35	9.8	9.8— 9.8	8.5	8.5 - 8.5	3.9— 7.5	5.3	4.3— 6.5	5.1— 5.6	5.3
20	51.3	42—57	1.88	9.4	9.4— 9.4	8.3	8.3 - 8.3	4.0— 9.0	6.5	5.1— 8.1	6.2— 6.9	6.6
20	49.8	41—56	1.02	9.8	9.8 †	—	—	6.0— 15.	10.0	7.9— 12.9	9.6— 10.7	10.2
20	47.8	41—53	0.62	9.6	9.6 †	7.3	7.3 †	11.0— 22.0	15.1	12.8— 18.6	14.8— 18.6	15.5
20	45.3	38—55	0.37	9.6	9.6— 9.6	7.35	7.35 †	21.0— 44.0	30.4	29.4— 37.1	29.1— 31.8	30.4
20	47.8	39—57	0.24	8.8	8.4— 9.2	7.65	7.65 †	38.0— 148	66.7	50.7— 88.1	62.8— 71.1	65.8
10	44.3	36- 57	0.13	9.2	8.2- 10.0	—	—	850 —5765	1714	1234 - 2379	1592 —1844	1607
10			0.07+	Only 40 per cent mortality occurred in 10 days								
Rome Hatchery stock (1956)§												
20	44.4	35—51	1.19	10.0	10.0 †	8.5	8.5 †	6.0— 14.0	10.0	8.0— 12.4	9.5— 10.5	10.3
20	45.4	33- 55	0.79	9.8	9.4— 10.0	—	—	7.0— 29.0	17.6	11.5— 27.0	16.0— 19.4	18.2
20	46.5	39—57	0.51	9.9	9.8—10.0	8.18	8.18 †	17.0— 71.0	42.7	29.2— 62.4	39.2— 45.4	44.8
20	48.6	42—58	0.36	9.5	9.1— 9.8	8.07	8.05—8.14	52.0— 121	81.1	68.0— 96.8	78.0— 84.4	81.8
20	46.7	40—54	0.35	9.7	9.4- 9.8	8.12	7.89 8.4	45.0— 152	93.6	70.6— 125	88.2— 100	94.7
20	43.9	39—52	0.26	9.7	9.4— 9.8	8.14	7.93—8.32	80.0— 295	147	102 — 209	135 — 159	146
20	42.9	39—50	0.20	9.8	9.7— 9.8	8.13	7.88—8.3	60.0— 460	204	112 - 369	178 - 233	214
								115 — 810	516	379 - 702	481 - 553	520

20	101.5	85—120	1.89	9.6	9.6— 9.6	—	—	5.8— 13.5	9.3	7.4— 11.7	8.9 — 9.8	9.3
20	106.3	76 –130	0.98	9.7	9.6— 9.8	8.5	8.5 †	8.7 - 20.3	13.9	11.0 - 17.4	13.2 — 14.6	14.0
20	103.5	82—124	0.68	9.6	9.4— 9.6	—	—	14.0 — 37.0	22.8	17.5— 29.6	21.5 — 24.2	22.7
20	104.4	89—120	0.48	9.5	9.4— 9.6	8.1	8.1 †	31.0 - 66.0	46.9	38.7 - 56.8	44.9 — 48.9	47.6
20	102.4	81—115	0.35	9.8	9.6— 9.8	7.6	7.6 †	53.0 - 109	75.4	61.5 - 92.5	72.1 - 78.9	75.4
20	104.8	84—119	0.20	9.6	8.8— 9.8	7.7	7.6 - 7.8	127 — 230	203	150 - - 275	190 - 217	202
20	100.4	85—123	0.15	9.6	9.4— 9.8	7.6	7.6 †	202 - 1410	479	287 — 801	428 — 537	471
20	105.5	81—138	0.12	9.2	8.8— 9.8	7.6	7.55—7.6	818 - 2608	1461	1025 2082	1350 — 1581	1508

* 10 fish per jar.

§ Rates of flow were as follows:
in 1954— 8 liters per hour to a 9-liter jar
in 1956—10 liters per hour to a 20-liter jar
in 1957—13 liters per hour to a 9-liter jar

† Only a single reading taken.

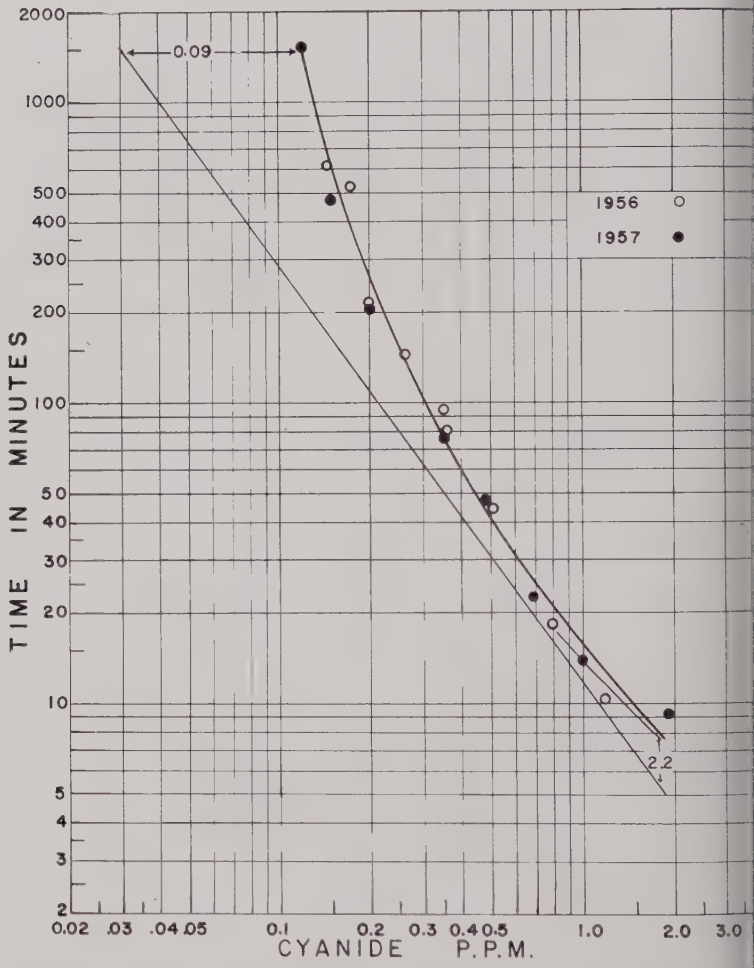


Figure 4. Cyanide toxicity curve for brown trout in Rome Hatchery sp water at 60° F. with oxygen near saturation, and the grap solution for the threshold concentration.

plotted against concentration in Figure 4 and a smooth curve constructed by inspection through the data. Some consideration given to variation of oxygen in constructing the curve. Compa with the curve obtained in Figure 2 illustrates the effect of red oxygen on the lethality of cyanide.

A line for the graphical determination of the approximate thres value and the equation of the curve (Burdick, 1957) has been a

igure 4. The threshold value implied in the curvature of the data ared to be about 0.09 p.p.m. of cyanide. The equation for the e was:

$$\log (y-2.2) = 1.06725 - 1.38325 \log (x-0.09)$$

n y=time to death and x=concentration of cyanide

Either the plotted curve or the equation may be used to calculate ime for 50 per cent mortality at 60° F. for concentrations lying n the plotted points. Since the threshold value is a function of urve, rather than an extrapolated value, it is believed that the for 50 per cent mortality may, in many cases, be derived with ively little error for concentrations lying between the last plotted t and the threshold. This would hold true only where the reaction- ucing mortality did not change from that represented in the nted data.

LMOUTH BASS

Bass for this study were obtained from the State hatchery at South lic during the summer of 1955 and placed in a pond at the Rome hery. Before use in experimentation these fish were placed in ugh in the laboratory building where they were acclimatized for weeks to the experimental water and to the temperature at which tudy was to be conducted. These fish were fed live food. Pro- res were similar to those previously reported, except for the 70° F. erature. Five fish were placed in 20-liter jars serving as aquaria he rate of flow was 10 liters per hour. Controls were used through- he course of study. In seven of the nine cyanide concentrations l, the mean oxygen concentrations varied by not more than ? p.p.m. from the saturation value for the temperature. Due to , or to inability to recover the stock from the pond, the number h available for use was limited.

The data are presented in Table 4, in the same manner as was for brown trout.

The logarithmic means in minutes were plotted against the con- ations and a curve was projected through the plotted points re 5). Graphical approximation of the threshold value was ned by the same method that was used for brown trout, except orrection by successive approximation in order to minimize the in the space between the times of 290 and 1,370 minutes. The figure represents a median, since no mean could be computed 100 per cent mortality was not obtained in 4,320 minutes. The

Table 4. Toxicity of Cyanide to Smallmouth Bass in Rome Hatch Springwater at 70° F.*

Number of fish§	Mean length (millimeters)	Range of lengths (millimeters)	Cyanide concentration (p.p.m.)	Mean oxygen concentration (p.p.m.)	Range of oxygen concentration (p.p.m.)	Range of time to death (minutes)	Antilog. of mean log. of time to death (minutes)	Range of standard deviation of mean log. (minutes)	Range of standard error of mean log.
10	60.6	56–62	1.98	9.4	9.4–9.4	6– 10	7.8	6.6– 9.2	7.4
10	64.2	59–68	1.43	9.8	9.8–9.8	9– 16	12.4	10.0– 15.5	11.6-
10	60.7	54–70	0.978	9.0	8.8–9.2	9– 21	15.4	11.5– 20.8	14.0-
10	63.3	58–73	0.755	8.8	8.2–9.4	17– 42	30.6	23.1– 40.5	28.0-
10	63.4	55–75	0.478	9.0	9.0–9.0	29– 54	42.8	34.6– 53.0	40.0-
10	62.8	58–68	0.338	9.0	9.0–9.0	59–110	80.5	66.0– 98.1	75.6-
10	64.2	60–70	0.243	8.6	8.4–8.8	68–235	133	87.9–200	116 -
10	63.2	56–65	0.175	8.8	8.6–9.0	213–477	290	222 –377	266 -
5			0.127				1370 †	100 per cent mort not reached in 3 da	

* Flow was at the rate of 10 liters per hour to 20-liter jars.
§ 5 fish per jar.
† Median value.

threshold appeared to be 0.104 p.p.m. of cyanide, for the condi of the experiment.

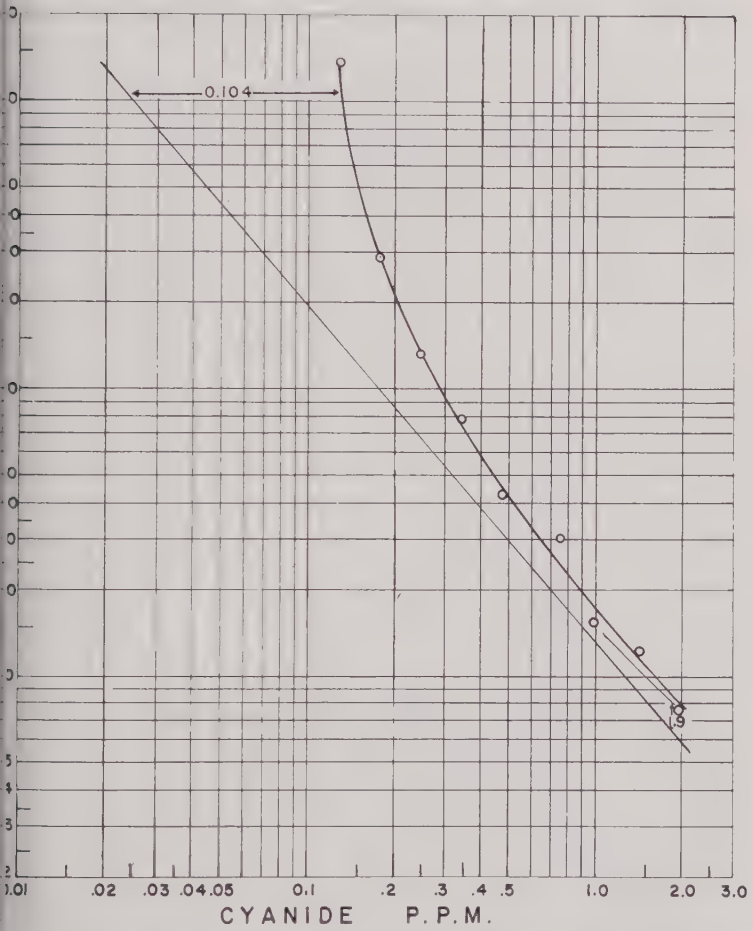
The equation for the plotted curve, by the previously used met can be represented by:

$$\log\ (y-1.9) = 1.12960 - 1.16047\ \log\ (x-0.104)$$

The curve or the equation may be used in the same manne was suggested for brown trout.

TOXICITY OF CYANIDE AT REDUCED OXYGEN CONCENTRATI

In 1949, New York enacted a law now designated as Article the Public Health Laws, which provided for the establishment of st ards which would become applicable upon the classification of water. Under this provision, minimum concentrations of disso oxygen of waters important to fisheries were established. For w



re 5. Cyanide toxicity curve for smallmouth bass in Rome Hatchery springwater at 70° F. with oxygen near saturation, and the graphical solution for the threshold concentration.

r fishes the minimum figure was set at 4.0 p.p.m., while the mum for trout waters was 5.0 p.p.m. (Water Pollution Control d, 1950).

Under these standards, fish might be required to withstand, at temporarily, these levels of dissolved oxygen, at the same time g subjected to the stress produced by the presence of specifically substances. It was considered desirable to obtain specific infor-on which could be used to evaluate the toxicity of various sub-ces to fish under reduced oxygen, both as a guide to the admission

of industrial wastes and as a criterion for enforcement of standa based on the physiological reaction of the species. Brown trout a smallmouth bass were used to establish the toxicity of cyanide approximately 5.0 and 4.0 p.p.m. of dissolved oxygen, respectively.

Southgate (1948) presented data from Southgate, Pentelow a Bassindale which showed an increased toxicity of cyanide to rainb trout with reduction in dissolved oxygen. Studies on brown trout l reported, also indicated the toxicity of cyanide solutions was sig cantly affected by the oxygen content of the test solutions.

Comparison of Methods for the Reduction of Oxygen

While a natural water may occasionally have its oxygen con reduced as a result of the introduction of substances capable of ente into chemical combination with the dissolved oxygen in the wate as the result of the entrance of ground waters that are deficient oxygen, such reduction occurs more commonly only from ac organic decomposition. This process also leads to an increase in carbon dioxide content and a lowered pH.

It would be difficult, if not impossible, to duplicate in the labo tory a water in which the oxygen had been lowered in this man and maintain the desired oxygen concentrations. The water wo have to contain a quantity of decomposable organic matter, so adju that continuation of the exercise of the unsatisfied biochemical oxy demand, plus the oxygen removed by fish respiration, would exa equal the entrance of atmospheric oxygen and thus maintain specified oxygen concentration.

Recognizing that test solutions would not duplicate a "natu water" in which the oxygen had been reduced with an accompany increase in carbon dioxide, it became necessary to produce an oxyg deficient water in the laboratory without altering the constituten increase or decrease significantly the toxicity of the substance to tested. The method should also allow easy duplication of the con tration.

Fry (1951) described a process by which the dissolved oxygen progressively reduced by counter-current removal by nitrogen gas column. The oxygen concentration was controlled by the rate passage of nitrogen, the rate of flow of the water and the position the column from which the water was drawn. In effect it increased partial pressure of nitrogen, so the nitrogen content of the water wo be somewhat increased. It would also result in the partial remo

e free carbon dioxide which might be present, with a possible ring of the pH.

A similar reduction of oxygen content could be effected by the cation of a vacuum. The reduced pressure would result in the val of oxygen, free carbon dioxide and nitrogen, in proportion e reduced pressure. In large volumes it would be a relatively slow ss unless the water was admitted to the vacuum in a thin stream.

A third method which could be used would involve the removal gases by boiling, followed by the addition of a measured volume ntreated water with a known oxygen content to produce the d concentration. Carbon dioxide and nitrogen would be present e experimental water in the same ratio to that in the untreated as would the oxygen. Boiling could also result in the precipita- of lime and result in a water with lower calcium content than the nal.

A theoretical calculation, based on the solubility and partial pres- of these gases, indicated that removal of oxygen by nitrogen gas d increase the nitrogen content somewhat, but that the change, mparison with the original water, would be less than what would from either of the other two methods, in which the soluble gen would be greatly reduced.

Before final decision on the method to be used, it was considered able to conduct comparison studies to determine whether the in- e in nitrogen over the normal content would result in increased creased toxicity of cyanide to brown trout, in comparison with the ods which would produce an abnormal reduction in the nitrogen nt. The oxygen sweep-out was carried out by means of a timed arge of nitrogen at a controlled pressure. A diffuser was used stribute the nitrogen through a measured volume of water in the re jar that was to contain the cyanide solution. The oxygen checked by chemical determination as the desired concentration pproached.

in all three solutions, frequent determination of oxygen content made in the test aquaria in order that a new solution could be duced if any change occurred in the oxygen concentration. It was ed to use a cyanide concentration of 0.31 p.p.m. The actual content d from that level to 0.315 p.p.m. The results are presented in e 5, together with the results of applying "Student's" *t*-test to are the values obtained by the three methods for the smallest mean to death of the fish. No significance was found in these compari- confirming the apparent similarity of the range of time to death.

Table 5. Comparison of the Effect on the Toxicity of Cyanide to Brown Trout of Three Methods of Reducing Oxygen in Rome Hatchery Springwater at 60° F.

Method of reducing oxygen	Number of fish	Mean length (millimeters)	Range of lengths (millimeters)	Cyanide concentration (p.p.m.)	Mean oxygen concentration (p.p.m.)	Range of oxygen concentration (p.p.m.)	Range of time to death (minutes)	Antilog. of mean log. of time to death (minutes)	Range of standard deviation of mean log. (minutes)	Range of standard error of mean log. (minutes)	Pooled variance	Value of t
Nitrogen gas	20	42.4	33—56	0.315	5.0	5.0—5.0	26—57	42.0	33.9—52.0	40.0—44.1	0.00802	1.31
Vacuum	20	41.3	33—55	0.313	5.1	5.1—5.1	27—62	39.5	32.4—48.1	37.7—41.2	0.00797	0.69
Boiling, with added springwater	20	40.9	32—48	0.310	4.95	4.9—5.0	25—59	41.3	33.4—51.1	39.4—43.3		

Based on the above, any of these methods would have been satis-
ry for testing cyanide. Sweeping out the oxygen by diffused
gen gas was chosen as the easiest and most rapid procedure, as
as being subject to the most accurate control. Nitrogen pressure
chosen for the low pressure system by which the cyanide solutions
to be transferred from the pressure jars to the test aquaria. This
d avoid any tendency for rapid increase in oxygen as a jar was
ied which might occur with the use of compressed air to effect the
ange.

VN TROUT AT THE OXYGEN "STANDARD" OF APPROXIMATELY
.P.P.M.

Brown trout from the Rome Hatchery were acclimatized for some
to the water and temperature at which this study was to be con-
d. The experimental aquaria consisted of 20-liter pyrex jars into
n the prepared solution of known oxygen content was conducted
e rate of 10 liters per hour. Pressure, controlled by a diaphragm
, was taken from a cylinder of nitrogen in order to prevent
-up of oxygen in the system. Rome Hatchery springwater was used
he temperature was held to $60 \pm \frac{1}{2}^{\circ}$ F. In four of the solutions
l, one-half the fish were used at the rate of 10 per jar, the other
at only 5 per jar. Comparison would then indicate whether the
was inadequate in the presence of the larger number of fish.
no significance was noted in the differences of the mean time
ath, the rate of replacement must be assumed to have been suf-
t and 10 fish were used per jar in the remainder of the concen-
ns.

t was desired to maintain the oxygen concentration at, or above,
.0 p.p.m. "standard" at all times. It was anticipated there might
me loss of oxygen to the nitrogen atmosphere in the pressure
especially near the end of the experiment when the ratio of gas
ater became large. In order to permit some oxygen loss, yet
tain at all times an oxygen content at 5.0 p.p.m. or slightly above,
n was removed with diffused nitrogen until the content in the
imental water was approximately 5.2 p.p.m. The oxygen con-
was not appreciably reduced during the period of study; therefor,
xygen averaged approximately 5.2 p.p.m. The data and the curve
ructed from it must be considered to represent this average
tion. It is not believed that the oxygen content slightly above
"standard" of 5.0 p.p.m. made any significant change in the
on of the curve with respect to time.

The data obtained are presented in Table 6. Since there was so indication of non-proportional variation in the time to death, logarithmic midmean was computed for the central 80 per cent the data in each cyanide concentration. These values were used constructing the curve in Figure 6. Graphical estimation of theoretical value indicated that under these conditions it was appro mately 0.080 p.p.m. of cyanide.

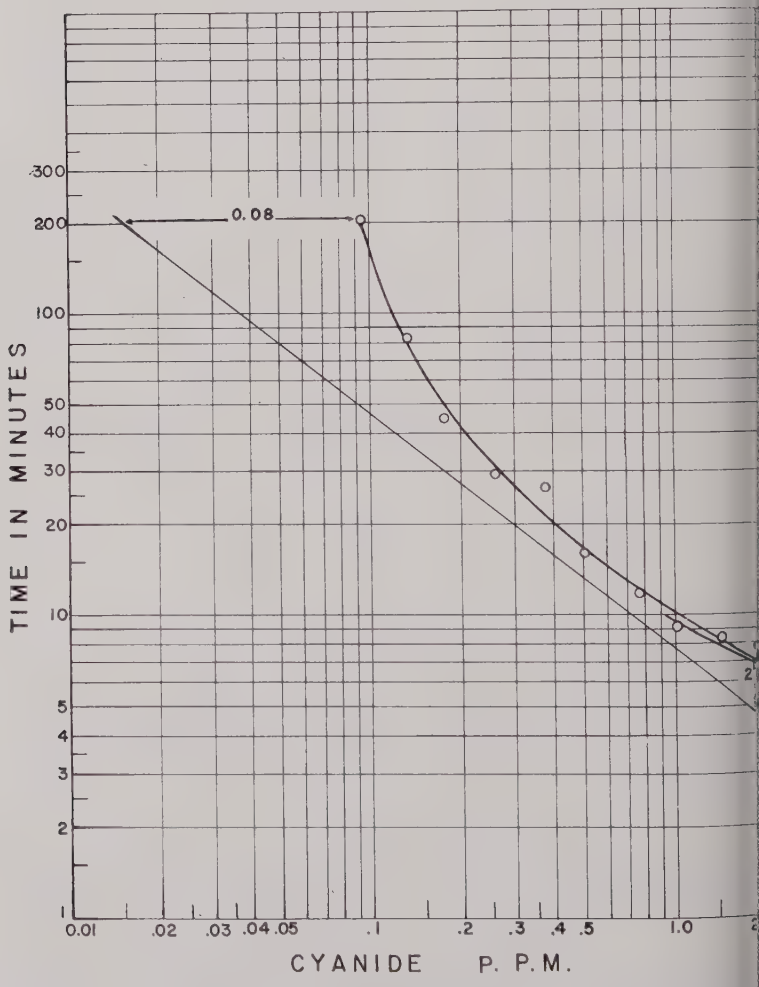


Figure 6. Cyanide toxicity curve for brown trout in Rome Hatchery sp water at 60° F. with oxygen approaching 5.0 p.p.m., and graphical solution for the threshold concentration.

TABLE 6. TOXICITY OF CYANIDE TO BROWN TROUT, AT A NEAR "STANDARD" OXYGEN LEVEL, IN ROME HATCHERY SPRINGWATER AT 60° F.

Number of fish	Mean length (millimeters)	Range of lengths (millimeters)	Cyanide concentration (p.p.m.)	Mean oxygen concentration (p.p.m.)	Range of oxygen concentration (p.p.m.)	Mean pH	Range of pH	Range of time to death (minutes)	Antilog. of mean log. of time to death (minutes)	Range of standard deviation of mean log. (minutes)	Range of standard error of mean log. (minutes)	Midmean (central 80 per cent of data)
20	52.4	40—65	1.98	5.2	5.2—5.2	8.18	8.10—8.25	6— 10	7.8	6.4 - 9.4	7.4— 8.1	7.8
20	56.7	40—70	1.46	5.2	5.2—5.2	8.18	8.15—8.20	4— 13	8.2	5.9 - 11.2	7.6— 8.7	8.4
20	53.2	42—64	1.00	5.1	5.0—5.2	8.05	8.05—8.05	6— 15	9.2	7.1 - 11.9	8.5— 9.8	9.1
20	52.9	37—69	0.76	5.3	5.2—5.4	8.05	8.05—8.05	9— 17	12.0	9.8 - 14.6	11.4— 12.5	11.9
10	58.4	50—68	0.51	5.2	5.2—5.2	8.00	8.00*	13— 27	16.6	13.6 - 20.3	15.6— 17.7	16.1
10	57.1	51—66	0.38	5.2	5.2*	8.00	8.00*	18— 32	26.1	22.1— 30.8	24.7— 27.5	26.6
20	57.4	49—66	0.26	5.3	5.3*	8.05	8.05*	12— 49	28.5	19.6— 41.4	26.2— 31.0	29.3
20	57.8	49—70	0.175	5.18	5.1—5.2	8.13	8.10—8.15	22— 86	44.1	30.6— 63.6	40.7— 47.9	44.1
20	56.5	50—70	0.132	5.2	5.1—5.3	7.85	7.85*	16—252	82.0	37.5—179	68.8— 97.6	83.9
20	63.2	55—75	0.095	5.0	4.8—5.4	—	—	33—920	202	76.9—528	163 —250	202

* Only a single reading taken.

Using the line formed on the graph by this procedure and successive approximation, the equation for the curve becomes:

$$\log (y-2.2) = 0.89354 - 0.77309 \log (x-0.080)$$

Solution for selected values of x indicates that either the g or the equation will provide satisfactory estimates of the time to de

Smallmouth Bass at the Oxygen "Standard" of Approxima 4.0 p.p.m.

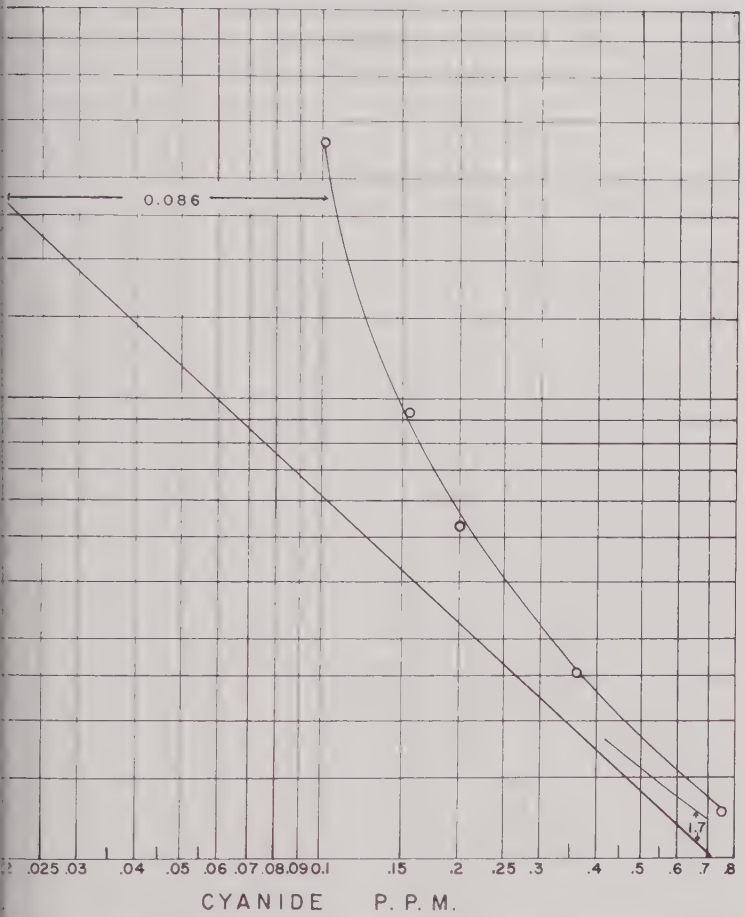
The bass remaining from the determination of the toxicity o at 70° F. for oxygen levels near saturation were used in this stud evaluate the toxicity near the minimum oxygen standard for w water fishes.

The experimental solutions were transferred by nitrogen pre from the pressure jars to 20-liter pyrex aquarium jars, solutions maintained at 70±½° F. Flow was at the rate of 10 liters per h The stock of fish that remained after the high-oxygen studie small, so only five were used at each concentration of cyanide ex the lowest, where 10 were used to correct for the larger spread w commonly occurs at low concentrations. Hatchery springwater used as experimental water for the cyanide solutions. Except fo 0.75-p.p.m. concentration, oxygen ranged from 4.1 to 4.2 p.p.m an average.

Table 7. Toxicity of Cyanide to Smallmouth Bass, at a Near "St ard" Oxygen Level, in Rome Hatchery Springwater at

Number of fish	Mean length (millimeters)	Range of lengths (millimeters)	Cyanide concentration (p.p.m.)	Mean oxygen concentration (p.p.m.)	Range of oxygen concentration (p.p.m.)	Mean pH	Range of time to death (minutes)	Antilog of mean log. of time to death (minutes)	Range of standard deviation of mean log. (minutes)	Range of standard
5	57.6	53-68	0.75	4.4	4.4*	8.2	11- 17	12.6	10.5-15 .1	10.0
5	57.0	55-60	0.36	4.1	4.1*	8.2	21- 29	25.2	21.7-29 .2	23.6
5	61.2	51-81	0.20	4.1	4.0-4.2	8.3	36- 70	52.9	39.5-70 .7	46.4
5	70.2	56-87	0.156	4.2	4.2-4.2	8.3	78-122	93.2	78.2-111	85.2
10	65.6	56-87	0.102	4.1	3.8-4.3	8.3	146-992	362	183 -715	292

* Only single reading taken.



7. Cyanide toxicity curve for smallmouth bass in Rome Hatchery springwater at 70° F. with oxygen approaching 4.0 p.p.m., and the graphical solution for the threshold concentration.

The data obtained from these studies are presented in Table 7. the number of fish available was so restricted, the use of a mid- was ruled out and the logarithmic mean, transformed to minutes, plotted in Figure 7 against cyanide concentration. Although ions from the curve drawn through the plotted points were small indicated close agreement between the several concentrations, dually the points cannot be assumed to have the same statistical icy that would theoretically have been obtained if more fish had vailable at each concentration.

Using successive approximations, a graphical solution for threshold value was calculated. The straight line formed in this culation appears in Figure 7. The threshold is estimated to be appr mately 0.086 p.p.m. of cyanide. The equation for the curve calculated and can be expressed as:

$$\log\ (y-1.7) = 0.86543 - 0.92335\ \log\ (x-0.086)$$

Solving for specific values of x indicated that this equation w serve as well as the curve for calculating the mean time to deat any concentration of cyanide falling with the limits of the graph.

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FURTHER STUDIES ON THE SMELT OF LAKE CHAMPLAIN

Robert G. Zilliox District Fisheries Manager
New York State Conservation Department

William D. Youngs Aquatic Biologist
New York State Conservation Department

ABSTRACT

Studies were conducted during February and March in 1948 and to determine the status of the smelt fishery in Lake Champlain. Data available for comparative purposes from a detailed study conducted dur similar period in 1929. Fishing is often conducted over a 24-hour period. N fishing is prevalent in the Port Henry area, and lights are used to illum the depths.

Sampling of the night catch indicated night fishing was no more sele for female fish than was day fishing; nor were older-aged female smelt ticularly more numerous in the night sample than in the day sample.

Two major races of smelt inhabit Lake Champlain and are referred the small race and the large race. The small race was found to be less num in the 1948 and 1950 samples than in the 1929 sample. Growth data compared for samples of the large race collected in 1929 and 1950. The gr of males and females, in the 1950 sample, showed no significant diffe between mean lengths for three of the five age classes tested. Similar tes the 1929 males versus 1950 males, and the 1929 females versus 1950 fem showed no significant difference for 8 of the 10 comparisons made. A interviews revealed an equally divided opinion as to a declining fishery. Suc ful smelt angling was found to be dependent upon safe ice conditions. No was seen for restrictive changes in fishing regulations at that time.

Fishing through the ice for smelt in Lake Champlain has be popular sport in both New York and Vermont waters for many y In most years, sufficient ice has generally formed by late Januar support a shanty-type fishery in the various smelt-fishing areas (Fi 1). The bulk of the angling is done from shanties, using one or hand lines per angler manipulated with "smelt sticks" (Figure When winter temperatures are agreeable, some anglers fish thr the ice without the protection of a shanty. Relatively few smelt caught other than through the ice.

In New York waters smelt fishing areas are found scattered Port Henry north to Chazy Landing, a distance of approximatel miles. One of the most popular and well known areas is in the vic

---

[1] This investigation was supervised by Dr. W. M. Lawrence, then S Aquatic Biologist, New York State Conservation Department. The au wish to acknowledge the excellent guide service, particularly during creel checking, provided by Frank Nels of the Department's Crown Fish Hatchery. They also wish to thank Dr. C. W. Greene, Chief, Bure Fish, New York State Conservation Department, for providing original data from his 1929 smelt study.

Figure 1. Portion of "shanty town" in a smelt-fishing area.

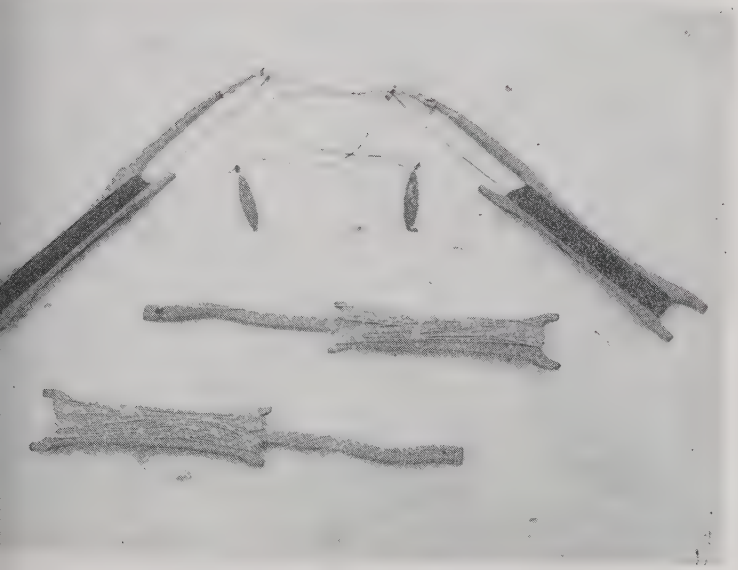


Figure 2. Typical smelt-fishing gear.

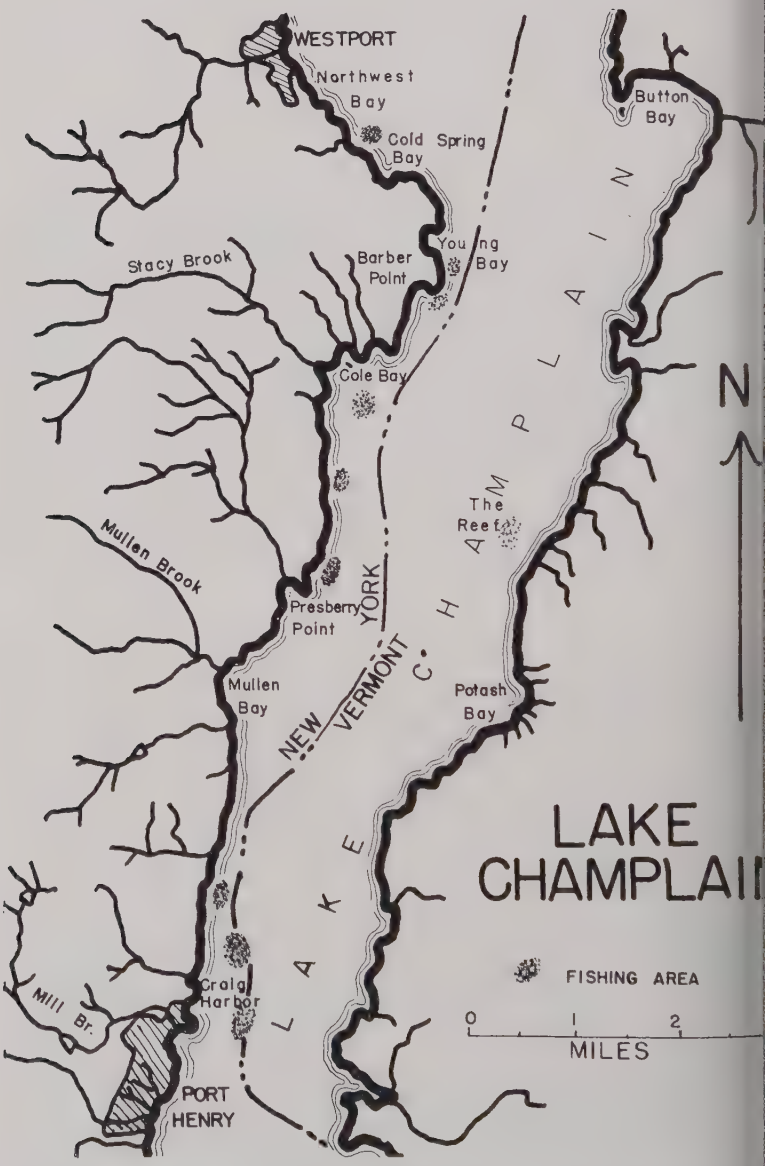
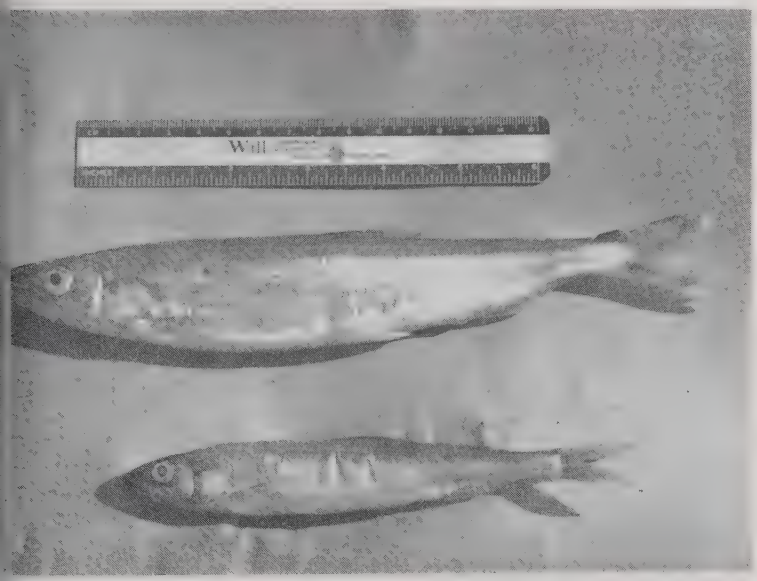


Figure 3. Map of Port Henry-Westport area in Lake Champlain sho
major smelt-fishing areas.

ort Henry (Figure 3). A rather specialized night fishery using
s was supposedly developed in this area years ago. Generally this
ves fishing inside a shanty, with two hand lines per angler, using
it lowered into the water to a variable depth. This light is often
led-beam unit or a bulb operated from a 6-volt car battery, al-
gh various other methods of inducing light to penetrate the water
ns are tried. Night fishing with lights can prove as productive
e angler as day fishing when the smelt are biting.

Certain aspects of the smelt fishery were investigated during the
1948-1950. Of primary concern was whether night fishing with
s was selective for mature female fish. The possibility of need
neasures of protection and evidence of depletion were also con-
ed. Growth data were collected for comparison with data obtained
29 (Greene, 1930).

Greene (*op. cit.*) reported in detail upon the smelt in Lake Cham-
. He showed that two major races, a small race and a large
inhabit the lake. No anatomical basis has been found on which
parate the races. However, their growth patterns are character-
lly distinct and provide a basis for separation in most cases
ire 4 . He also found that the small race matured at two winters,



4. Racial comparison of smelt from Lake Champlain: upper fish, 3-winter specimen of large race (233 millimeters); lower fish, 3-winter specimen of small race (158 millimeters).

while only approximately one-third of the large race matured at same age. In 1937, a 6-inch size limit, which had been in force 26 years, was removed. This size limit caused virtual protection the small race inasmuch as the average length of the oldest age gr in 1929 was 160 millimeters (6.3 inches).

DESCRIPTION OF THE LAKE

Lake Champlain is on the boundary between New York Vermont, and extends northward into Canada for a distance of a 5 miles. Douglas (1931) gave its greatest length, from White (N. Y.) to its northern extremity in Canada, as 107 miles. Its gre width is about 12 miles. The lake is oligotrophic in nature wi maximum recorded depth of 399 feet. The surface area for the e lake, excluding islands, is 435 square miles.

Greeley (1930) recorded some 52 species of fish inhabiting lake. Other than smelt, warm-water game and pan fishes comp most of the anglers' summer and winter catch. The smelt in Champlain are not subject to a size, season or creel limit. They be taken only by hook and line fishing.

GENERAL OBSERVATIONS CONCERNING THE SMELT FISHE

As might be expected, many theories are offered by angler explain why the smelt do or do not bite at certain times. Both un ice factors such as currents and turbidity and over-ice phenom such as wind and temperature are cited. This study, as well as a 5- lake-wide winter creel census during the years 1951 to 1955, sho local and lake-wide variations in the smelt catch. Some observa concerning the catch may be cited. In the early part of March 1 angling success was poor in the two main smelt areas off Port He In a lightly fished area somewhat north of these (Figure 3), indivi catches of between 20 and 30 pounds were being recorded. A sim situation occurred in the middle of March 1950 when large cat were being made in an area called "the reef" in Vermont w (Figure 3), while mediocre catches were being made in New waters. A peculiar catch distribution can exist in a small area con ing 20 or 30 shanties. Occasionally a few shanties in the area wi providing the best fishing. The situation can change to where p tically all shanties are affording good fishing and this can preva the length of the entire fishery. Because of such varying patter success, quite a few anglers, particularly those who fish for the ma continually move their shanties to enjoy the best possible fishing.

OBJECTIVES AND METHODS

This investigation was primarily concerned with:

1. Determination of the proportion and age distribution of female smelt in a night-angling sample for comparison with similar data collected during the day. In all cases mention of night angling refers to fishing with the use of lights.
2. Comparison of the racial composition of the catch in 1929, 1948 and 1950.
3. Comparison of growth among the large race of smelt for 1929 and 1950.
4. Collation of information from interviews with anglers, market fishermen, and storekeepers marketing smelt, concerning a possible decline in the fishery.

In February and March of 1948 and 1950 ice conditions were ble for conducting the investigation. The winter of 1949 was cterized by poor ice conditions, resulting in a paucity of data. g any day or night creel check, all shanties and anglers in a g area were interviewed, and data were taken for the complete in possession at that time. In all cases, total length was recorded llimeters. The age of the smelt was noted in terms of winters. all specimens were collected in February and March, before new h was resumed, a one-winter specimen would be a fish that had completed one growing season, a two-winter fish would be one had almost completed two growing seasons, etc. Scale readings reene (1930) and the senior author show that the large race has nal life span of six winters, while the small race has a normal an of four winters.

FINDINGS AND DISCUSSION

rowth, racial composition, and catch data were acquired during 1948 and 1950. Information pertaining to night fishing was ed in 1950. The sex ratio of the day sample was recorded in but not in 1948. Too few specimens of the small race were ed in 1948 and 1950 to permit growth comparisons with the 1929

Fishing

ex was determined for 984 smelt taken mainly in the Port Henry

area during March 1950. This sample included fish creeled by ang during both day and night. Females comprised 38 per cent of smelt examined from night creels, and 44 per cent of 318 sm examined from day creels. In a sample of 250 smelt (large ra caught during daylight hours in late February and March 1929, fem comprised 41 per cent.

The age composition was determined for a sample of la race female smelt caught in March 1950. Of 160 taken at nig 50 per cent were four-winter and older specimens. Of 131 ta during the day, 58 per cent were in the same age group.

These data indicate that night fishing was no more conducive creeling female smelt than was daylight fishing. They also indic that night fishing did not result in creeling a preponderance of old age large-race female smelt.

Racial Comparisons

Table 1 shows the racial composition of samples collected du 1929, 1948 and 1950. The three samples represent daylight catc

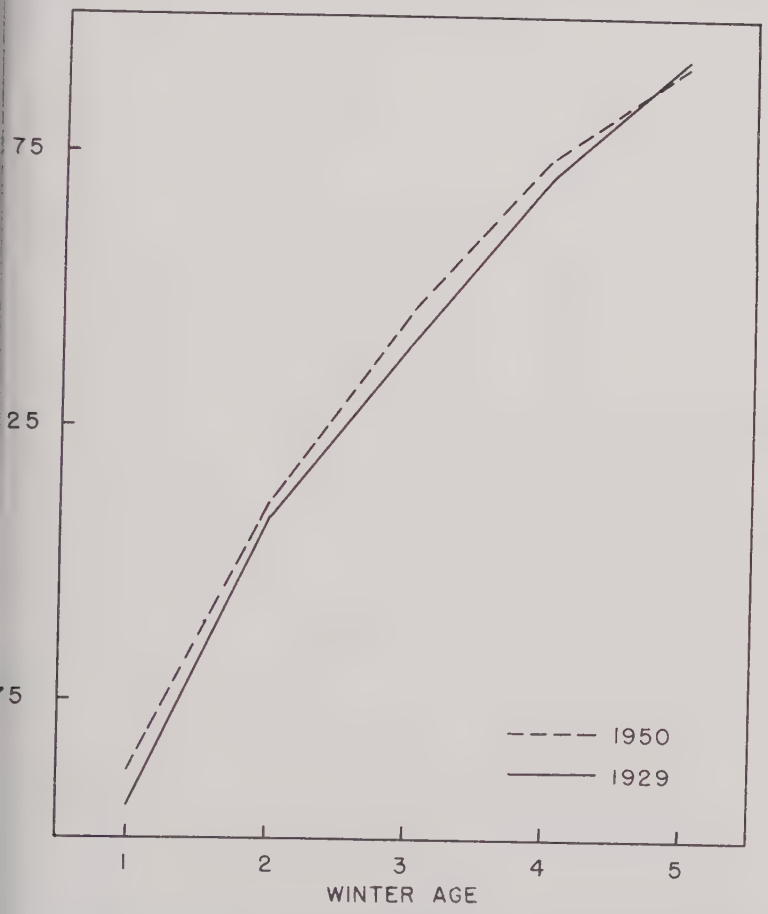
Table 1. Racial Composition of Smelt in Lake Champlain

Year	Large race		Small race	
	Number	Per cent	Number	Per cent
1929.....	265	69.7	115	30.3
1948.....	258	92.8	20	7.2
1950.....	308	95.7	14	4.3

The 1948 and 1950 samples comprised a much smaller percent of small-race smelt than did the 1929 sample. If the samples indicative of the racial composition in the lake at the time they w taken one may speculate upon the reason for the fewer num of the small race in recent years. Spawning failures, population sh angling following the removal of the 6-inch size limit in 1937, predation by other species of fish can be mentioned. Smelt fisher in recent years maintain that their catches contain larger fish. smaller proportion of small-race fish, entering catches in recent y would provide a basis for this observation.

WTH COMPARISONS

To determine whether any drastic change in growth had occurred e large race of smelt, growth data obtained in 1929 (Greene, 1930) 1950 were compared. These data are given in Table 2 and re 5. Data taken in 1948 are included in Table 2 for completeness, are not strictly comparable since sex determinations were not made at year. Points representing the mean lengths at the various ages, ven in Figure 5 for 1929 and 1950, are class means derived by aging the sex means for each age class. It is necessary to use class



5. Comparative rates of growth in 1929 and 1950 for large race of smelt in Lake Champlain as indicated by average length of specimens of different ages.

Table 2. Growth of Large Race of Smelt in Lake Champlain

Age*	1929						1948 (sexes combined)			1950					
	Male			Female						Male			Female		
	Number	Mean length§	Standard deviation	Number	Mean length§	Standard deviation	Number	Mean length§	Standard deviation	Number	Mean length§	Standard deviation	Number	Mean length§	Standard leviation
1	6	159.3	8.45	7	154.1	8.93	3	165.0	5.29	9	162.0	11.76	4	163.8	13.57
2	64	208.5	11.29	45	208.4	12.60	27	209.4	22.31	29	208.8	12.74	18	213.5	19.00
3	50	238.9	14.81	31	240.6	17.25	111	248.0	18.41	42	238.6	11.87	33	253.0	10.80
4	17	260.5	15.13	14	279.4	27.48	79	269.4	13.45	56	271.3	13.58	28	276.4	13.14
5	9	279.6	10.74	5	306.6	9.84	29	283.2	11.34	36	287.5	9.72	45	298.2	11.80
Sex class mean		229.4			237.8			xxx			233.6			241.0	
Total class mean		233.6						235.0			237.4				

* In winters
§ In millimeters

ns to obtain an unbiased estimate of the population length at the ous ages, since the data of Table 2 suggest possible differential rth of the sexes.

A comparison of the growth between sexes was derived from the sample. Of the five age groups involved, differences in length een males and females were significant only for ages 3(t=5.50) 5(t=4.48). However, there was a general trend which indicates on the average female smelt are larger than male smelt. This l is also evident for the 1929 sample, but was not tested. Conse- tly, separate comparisons of lengths of male and female smelt were e when testing the 1929 data against 1950 data.

Comparisons of lengths of smelt for 1929 and 1950 are given in e 3. Of the ten comparisons made only two differed significantly. ough the smelt sampled in 1950 averaged longer than those sam-

E 3. COMPARISON OF GROWTH OF LARGE RACE OF SMELT IN LAKE CHAMPLAIN FOR 1929 AND 1950

Statistic	Age (winters)				
	1	2	3	4	5
Male					
length (in millimeters)					
029	159.3	208.5	238.9	260.5	279.6
950	162.0	208.8	238.6	271.3	287.5
difference	2.7	0.3	0.3	10.8	7.9
ard error of means	5.22	2.75	2.78	4.09	3.93
of t	<1	<1	<1	2.64*	2.01
Female					
length (in millimeters)					
929	154.1	208.4	240.6	279.4	306.6
950	163.8	213.5	253.0	276.4	298.2
difference	9.7	5.1	12.4	3.0	8.4
rd error of means	7.58	4.86	3.62	7.75	4.74
of t	1.28	1.05	3.43**	<1	1.77

ignificant at the 5 per cent level.
ignificant at the 1 per cent level.

pled in 1929, there is little evidence to indicate a substantial chang growth rate in the smelt population between these two years.

Status of the Smelt Fishery

Interviews with over 200 anglers in the Port Henry-Westport a between 1948 and 1950 revealed opinion to be equally divided a a declining fishery. Many of these anglers had been fishing the over the 20-year period 1931-1950. Most merchants in this area sta they did not handle the amount of smelt for sale in the decade 19 1950 that they did in 1931-1940. However, it must be remembe that during the period 1931-1940 there was much unemployment. more anglers may have fished for the market in order to supplem their income. Information gathered from direct questioning we indicate that no apparent decline in the yield of smelt has occu in recent years, that the catch is more widely distributed amon greater number of anglers than it formerly was, and that more s are being utilized by the angler (and his friends) resulting in smelt being marketed.

Unpublished data from a New York State Conservation Dep ment winter creel census conducted on Lake Champlain during years 1951 to 1955 adds some interesting statistics. In a portio the lake comprising the Port Henry-Westport area, smelt contribu between 91.3 and 96.3 per cent of the total catch of fish in fou the five years. In 1953 smelt contributed 4.4 per cent of the ca This poor contribution was correlated with unsafe ice conditions year and the inability of the anglers to reach the smelt areas with t shanties. In the 8-year period from 1948 to 1955 ice conditions the correlated smelt harvest were as follows: 1949 and 1953 p 1951 and 1955 fair; 1948, 1950, 1952 and 1954 good. It is appa that ice condition is an important factor affecting angler catch. Ass ing these conditions are indicative of what will occur in future y it does not appear likely that angling will seriously affect the s fishery. No need was seen for restrictive changes in fishing regula at the time this survey was completed.

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CARBON DIOXIDE AS A LIMITING FACTOR IN TROUT TRANSPORTATION[1]

David C. Haskell Fish Hatchery Helper
New York State Conservation Department

Richard O. Davies Fish Hatchery Foreman
New York State Conservation Department

ABSTRACT

Carbon dioxide accumulation is shown to be a major limiting factor in fish portation in tanks: high concentrations will be tolerated if the rate of build-up w, but, when the rate of increase is high, as with heavy loads, the fish will ne distressed. Carbon dioxide may be removed by passing large volumes of n or compressed air through the water; by bailing the water continuously; circulation and aeration: by the addition of chemicals, the latter at least r close experimental control. With effective control of carbon dioxide ecirculation and aeration, loads may be increased by the addition of en sufficient to maintain a minimum of 10 p.p.m.

Success in transporting fish in tanks depends primarily on satisfying metabolic requirements. The first steps usually taken are measures ned to reduce the rate of metabolism, e.g., carrying the fish at temperatures and thoroughly starving them before shipment. It the same basis that tranquillizers, such as sodium amytal, have used.

Even though the metabolic processes have been slowed down, it o necessary to control the gaseous content of the water, keeping thin limits tolerable to the fish. Maintenance of sufficient oxygen primary requirement and a minimum practical limit of about p.m. is well established. Recently, Phillips *et al.* (1953, 1954) ted an extensive series of tests which indicate that the accumula- in the water of metabolic products from the fish sets an upper of carrying capacity unless removed.

The metabolic products produced by fish are many, and their re is not well understood. They may, however, roughly be divided two groups: those which may be removed by aeration, which in-

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nks are due to Dr. A. M. Phillips, Jr. and Donald R. Brockway of the rtland Experimental Hatchery for advice and assistance, and especially to rge Burdick, senior aquatic biologist, and Howard Dean, aquatic biologist he New York State Conservation Department, who spent much time in ising and assisting with the chemical problems and analyses. L. Bouchard L. E. Miller assisted with the preliminary experiments.

clude carbon dioxide; and a variety of compounds such as ammo urea, etc. which are not readily removed by aeration.

Since most workers in the past have used oxygen content of water as the sole criterion, it is interesting to note that Prevost Piché (1939) observed that, as loads of fish were increased, maintenance of sufficient oxygen did not always insure successful tr portation. In one experiment with a heavy load, 2,000 fingerling 2.1 cubic feet of water, they observed that the fish "soon showed abnormal agitation, and at the end of thirty-five minutes, seventy- of them had turned on their backs, and thirty-four subsequently di These workers found that they could alleviate this condition by eff ing a vertical distribution of the fish in the tank, using a serie horizontal screens spaced one above the other with a proportion of fish confined between each pair. The maximum loads carried v about equal parts of water and fish, or about 62.5 pounds per c foot of water.

Haskell (1941) observed the same condition, and noted tha was possible with very heavy loads to keep the fish alive, altho in poor condition, if the oxygen supply was increased and its minim level kept at about 15 p.p.m. The loads carried were about 41 pou per cubic foot of water.

Phillips *et al.* (1954) were able to hold successfully densitie trout up to about 45 pounds per cubic foot of water using compre air aeration, low temperatures, 72-hour starvation, and sodium amy In their tests the fish were carried in small tanks (7 liters of wa for 12 hours, and a test was judged to have been successful when mortality was observed after the fish had been held overnight follow the test.

PRELIMINARY EXPERIMENTS

In the spring of 1956, a series of experiments was made in attempt to duplicate in large tanks the densities carried in Phil experiments. The tanks were the standard type used in New Y 18 inches wide and 48 inches long. Oxygen or air was liberated f a perforated rubber hose, 8 feet long, in the form of a loop in bottom of the tank. Brown trout about 7 to 7½ inches long were u Tests were made at 34° and 50° F., with either oxygen or compre air aeration. In some of the tests at 34° F. sodium amytal was u The weight of fish used was 160 pounds per tank, with a water d of 16 inches (total depth 21.1 inches) or 20 pounds of fish per c foot of water.

The results were rather uniformly unsatisfactory. The fish were asy during most of the tests and reached a condition which war- ed termination of an experiment after 2½ to 3½ hours. Some tality resulted from each test, and observation of the fish as they unloaded indicated that they might have smothered.

In a second series of experiments, brook trout were carried under same conditions and the results were about the same. However, in experiment using oxygen aeration, 200 pounds of brook trout were ied successfully for 2½ hours. In this test the oxygen supply was t 100 cubic feet per hour, or about 50 to 70 times the "normal ". In another test using compressed air and brown trout with a high rate of air flow, the fish carried fairly satisfactorily.

Using these results as a background, an extensive series of tests made to determine the oxygen flow required for loads of different ities, the compressed air flow required, and finally, to investigate actors which limit the maximum load.

OXYGEN OR AIR FLOW REQUIRED

Throughout all of the following tests brown trout were used that ged 5 to 6½ inches long (20-10 per pound). Since the tests red a period of several months it was impossible to standardize the All fish used were starved 72 hours before being used in a test. All aeration, either oxygen or air, was through a perforated rubber In the first series, repeated tests were made at a given weight sh until the approximate oxygen flow at 50° F. for this weight determined. The safe limit was judged either by failure to carry ish successfully or by the lowest oxygen level occurring. Similar riments were made using compressed air. In all tests the water

e 1. Approximate Minimum Flows of Oxygen and Compressed Air Required to Carry Successfully Various Weights of Fish*

Weight of fish§	Oxygen flow†	Air flow†
70	1.2—	6.0
100	2.0—	12.0—
150	4.0	24.0

rown trout.
pounds; tank contained 8 cubic feet of water in each case.
ubic feet per hour.

depth was 16 inches before the fish were added. Table 1 summar the results.

The values followed by a minus sign in the table were belie to be slightly high but not enough so to warrant another experim In all tests the fish were carried successfully at the values given. is interesting that the air required was approximately five to six ti the amount of oxygen necessary for the same load. This may be rela to the fact that air is one-fifth oxygen.

Other Factors Influencing Transportation Succes

With a load of 200 pounds of fish, an oxygen flow of 4.8 c feet per hour was sufficient to maintain "acceptable" values of oxy (7.0 p.p.m. minimum), but the fish did not survive satisfacto Similarly, 36 cubic feet of compressed air maintained the oxygen l above 4.7 p.p.m. but again mortality was excessive. The remain of the tests were concerned with a study of the conditions which ca failure when the load was increased from 150 to 200 pounds, equa a change from 18.7 to 25 pounds per cubic foot of water.

Water Movement

From the failure to carry loads in excess of 18.7 pounds cubic foot, except when enormous quantities of oxygen or air w used, it was first thought that movement of the water was necess since the large volume of gas kept the tank water in motion. A pu was connected to take water from the bottom at one end of a t and return it to the bottom at the opposite end. Tests were mad assure that this did not aerate the water. When it was attempte carry 200 pounds of trout, the test failed. Various modifications of position of the water inlet were made, all below the surface so as to aerate, until it was established that motion of the water was not required factor.

Bailing

During the previous tests it had been found that a few min bailing, when the fish were in "bad shape", would cause then recover. Since attention, at that time, was directed to oxygen, a was made to see what effect bailing would have in maintaining oxy

A tank was loaded with 70 pounds of fish and left until the became distressed. The fish were removed, the oxygen content measured, and the water was then bailed for 5 minutes with a

oxygen concentration was 10 p.p.m. when the fish were intro-d; the fish reduced it to 3 p.p.m. and bailing brought it up to p.p.m. in 5 minutes. Evidently bailing is an effective method of tion.

Since bailing proved effective, another test was made. Seventy ds of 6-inch unstarved brown trout were loaded and held by ng the tank continuously, but without adding air or oxygen in other way. This test was made at 50° F. At the end of 30 minutes oxygen had dropped from 9.3 to 6.7 p.p.m. and at the end of minutes it was 6.8 p.p.m. Apparently constant bailing would have e it possible to carry these fish continuously.

During subsequent tests, whenever fish were "distressed" and it desired that they recover, bailing was used. No more effective od of altering the gaseous content of the water toward normal es was found.

E OF CARBON DIOXIDE

In one of the tests at this time, when the fish were distressed, the entration of carbon dioxide in the water was measured and found e 26 p.p.m. Using this as a lead, a large number of tests was e in which both oxygen and carbon dioxide were measured. The rvations indicated: (1) whenever carbon dioxide is kept below .p.m., with reasonable values of oxygen and temperature, the fish in in good condition; (2) when carbon dioxide reaches about t.p.m. the fish become distressed; (3) the degree of distress depends ie rate at which the carbon dioxide is building up. Thus, with rate loads, the carbon dioxide level will reach 25 p.p.m. and the will be slightly uneasy. The carbon dioxide will continue to rise eventually may reach 60 p.p.m.; however, the fish will be no more sy than they were at 25 p.p.m. On the other hand, with loads of pounds, the carbon dioxide builds up much faster and after it s 25 p.p.m. the fish are very soon in great distress.

To check these observations further, a cylinder of carbon dioxide obtained and a second liberator hose connected to this supply was n the tank. In the first test about 25 fish were put in the tank carbon dioxide bubbled in. Its concentration rose to 60 p.p.m. out 2 minutes. Every trout rolled over and laid on the bottom as gh dead. When placed in fresh water, they eventually recovered. Several other tests were made in which the rate of build-up of n dioxide was somewhat slower. Even though 15 minutes were

allowed to bring the concentration to 26 p.p.m., the fish showed sig of being in trouble at the end.

Carrying a "normal" load of 70 pounds of fish in 16 inches water, with oxygen aeration but no water recirculation, the carb dioxide built up to 33 p.p.m. at the end of 3 hours. Fish were in go shape. At the end of 5 additional hours, the carbon dioxide was s 33 p.p.m. and the fish were all right.

METHODS FOR CONTROLLING CARBON DIOXIDE CONCENTRATIONS

One method of removing carbon dioxide has already been d cussed, namely, bubbling enormous quantities of another gas throu the water. Both oxygen and compressed air were successfully used.

Water recirculation and aeration were also tried and fou effective. For this, two experimental arrangements were used. Fi recirculation of the water, from one end of a tank at the bott through a pump, and back to the other end of the tank, with the of the hose 3 to 4 inches above the water and headed down so as direct the water into the tank in a solid stream. In the second set-u the recirculation was the same except that two tanks were connect together at the bottom was a 2-inch hose. The water was pumped fr the tank holding the fish, at the bottom of one end, through the pu and into the second tank from which it flowed by gravity back i the first tank. Thus the aeration was accomplished in the additio tank. The pump used recirculated 35 gallons per minute. The resu obtained by the two methods were essentially the same except t when, in the first case, the flow was directed into the tank holding t fish it created so much turbulence that the fish were constantly bei carried around and seemed somewhat less "happy".

In one test, 200 pounds of fish were placed in 16 inches of wat This represented 24.5 pounds per cubic foot and the resultant to depth became 22¾ inches. They were carried for 2 hours. In ad tion to water circulation, oxygen was bubbled in at a rate of 4.8 cu feet per hour. At the end of 2 hours the water was lowered to 19 inches; the fish then equalled 30.0 pounds per cubic foot. At t end of the third hour from the start, the water was lowered to 16 inches (38.7 pounds of fish per cubic foot). At the end of 4 hours t water was lowered to 15 inches (46.5 pounds of fish per cubic fo and the fish were carried one more hour. At the end, and throughc the experiment, the fish were in good shape. Oxygen ranged fr 8 to 10 p.p.m. during the test and carbon dioxide from 5 to 7 p.p.

In another test, 200 pounds of fish were carried for 12 hours in nches of water (46.5 pounds of fish per cubic foot) and oxygen ied at 4.8 cubic feet per minute. Water was recirculated, and ater temperature held at 44° to 46° F. Fish were in good shape e end of the tests. Twelve (out of about 2,000) were found dead ext morning, including handling losses. Oxygen was 9 to 10 p.p.m. arbon dioxide was below 11 p.p.m.

Further tests were conducted with the same set-up but with an- pump which recirculated $3\frac{1}{3}$ gallons per minute. By the use of efficient aerators on the end of the hose where the water was ned to the tank, results were similar to those described above.

LIMEWATER TESTS

Throughout the foregoing experiments, there was no specific proof reduction in carbon dioxide was the real cause of the improvement rrying capacity. When the carbon dioxide was reduced by aera- many other products, if they existed, might have been removed ll.

The addition of limewater to a solution containing carbon dioxide rly specific in reducing the carbon dioxide without producing chemical changes. Thus, if the addition of limewater would the fish to be less uneasy and reduce the carbon dioxide, it be considered reasonable proof that the carbon dioxide was lly the causative agent of the trouble in transportation.

A load of 200 pounds of fish was held without water aeration for 20 minutes. At the end of this time they were very uneasy and rolling over. Two and one-half quarts of limewater were added tank and within a minute the fish were much calmer. After 5 es, however, when the limewater had become less effective, they began to show slight signs of uneasiness.

Data taken indicated that, in the tanks used, 150 pounds of fish ced dissolved carbon dioxide at a rate of approximately 0.024 ls per hour.

A test was made in which 150 pounds of trout were held in 15 of water (29.4 pounds per cubic foot). Oxygen was supplied ate of 4.8 cubic feet per minute. Water was recirculated at a rate gallons per minute *without* aeration, merely to insure mixing. water was continuously added to the water as it reentered the tank rate of 340 cubic centimeters per minute. The rate was later ed to 300 cubic centimeters per minute. This proved an excess, the carbon dioxide dropped to zero. The fish were carried for

3 hours without difficulty, and seemed to be in good shape w unloaded. About 25 dead fish were found the next morning, of a of about 1,200. This density of fish could not have been held 30 minutes with oxygen aeration alone.

DISCUSSION

It appears that, when loads of yearling brown trout excee pounds per cubic foot of water, maintenance of satisfactory ox levels (10 p.p.m. or more) is not sufficient to insure safe transp tion. Evidently the accumulation of metabolic products, princi carbon dioxide, is a major limiting factor. Loads may be fu increased if the dissolved carbon dioxide is reduced by (1) aer either by bailing or water recirculation, (2) purging by bubbling quantities of oxygen or compressed air through the water, (3) add of limewater. Although the addition of limewater effectively re carbon dioxide, this method is probably suitable for experim purposes only, since the amount of limewater added must be carefully controlled.

The finding that carbon dioxide is a limiting factor seems tradictory to the work of Phillips *et al.* (1954) who went beyon density of 19 pounds per cubic foot without difficulty, but event reached another limit measured by an accumulation of another of metabolic products for which ammonia was used as an index analyzing the differences in the experiments, it appears likely th their work, using compressed air and very small tanks, the air effectively purged the carbon dioxide.

The fact that the addition of limewater permitted carrying h loads is presumptive proof of the correctness of the assumption carbon dioxide was the limiting factor in these experiments.

Throughout the tests at heavy concentrations, it was found the fish survived better if the oxygen was maintained at 10 p.p.m higher. This probably reflects the work of Black *et al.* (1954) found that dissolved oxygen and carbon dioxide values are interre in their effects on fish. Hence, with high carbon dioxide values, oxygen levels are required. Thus, even with "effective" aeratio water recirculation as used by many agencies in their transport tanks, it has been found that, if oxygen is added, the maximum de of fish may be increased beyond the limit permitted by aeration a This apparently results from the fact that, with heavy loads recirculation or air aeration, the dissolved oxygen level will be siderably below the saturation value of roughly 10 p.p.m. With ox

this level and carbon dioxide held at or below 10 p.p.m., densi-
of yearling brown trout as high as 60 pounds per cubic foot of
have been carried experimentally. Thus the best ultimate solu-
may be recirculation plus the addition of oxygen.

The factors limiting the transportation of fish in tanks seem to
this order: oxygen depletion, carbon dioxide increase, ammonia
ase.

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EFFECT OF THE MANDIBLE RING TAG ON GROWTH AN CONDITION OF FISH[1]

William D. Youngs Aquatic Biologist
New York State Conservation Department

ABSTRACT

The effect of mandible ring tags on length and condition of fish studied for five species, namely, smallmouth bass, landlocked salmon, trout, brown trout, and rainbow trout. Length and condition were com in ten instances. Length increments of tagged and untagged fish significantly different in seven instances, and condition was significantly diff in one instance. Mandible ring tags caused no additional mortality in rai trout. For the other species, samples were not suitable for calculating mor

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Placement of some foreign object on or in the body of a fish long been used as a means for later recognition; Rounsefell and (1945) described 18 methods of tagging fish. Tags are used for va purposes among which are making population estimates, racial st and age determinations, and studying migration routes, the pa stream theory, survival of planted fish, mortality and growth r However, if tagging is used to determine a vital statistic of a population, such as mortality or growth, care must be taken to d and evaluate any change in that statistic caused by the presenc the tag.

Shetter (1937), using mandible ring tags, found no differenc the growth of tagged and untagged brook trout under hatchery co tions. Schuck (1942) showed that jaw tagging had a highly signifi effect on the condition of tagged wild brown trout in Crystal C (New York) when compared with untagged trout from the s

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[1] Derived from an M.S. thesis presented to the Graduate School, Co University. Dr. Dwight A. Webster, Professor of Fishery Biology, Co University, suggested the study and made available data on smallm bass, landlocked salmon, and brook trout. Dr. Alfred W. Eipper, Rese Associate, made available the use of farm ponds and equipment, and as in the field work. Dr. Douglas S. Robson, Assistant Professor of Biol Statistics, aided in certain phases of data analysis. The photograph taken by Douglass M. Payne, Laboratory Technician, Department of Cons tion. The cooperation of the following pond owners is acknowledged: R Chatfield, Lane Cooper, Charles Ettenberger, Howard Harvey, Fred W and H. R. Wilbur. The author also wishes to extend his thanks to Richar Hatch, Wilbur L. Hartman, William A. Lund, Paul C. Neth, and Richar Wahl, graduate assistants, as well as to Richard Dumas, C. W. Lyon, H Cook, and William Flick for their assistance in field work. The data Follensby Jr. Pond and Long Pond on the Brandon Preserve were made sible by cooperation of Mr. and Mrs. Donald P. Ross, Montchanin, Dela

ation. Cooper and Benson (1951) found that tagging had no on the condition of tagged stocked hatchery brook, brown, and w trout in the Pigeon River (Michigan) when compared with pped fish from the same lots. Pechacek (1956) compared growth ndition for several cold-water species. He showed that coefficients dition decreased on the average for tagged fish. He also showed agged fish did not maintain their natural growth as judged by rison with untagged members from the same population. che and Bond (1957) stated that 1- and 2-year growth increment for lake trout showed a definite retardation of growth as a of jaw tags. Corson (Anonymous, 1957) found growth rates gged and untagged hatchery rainbow trout to be very similar. (1957) found untagged brook trout gained more in length and t than did tagged brook trout under the same conditions; how- e also found the difference between condition factors of tagged ntagged trout varied with the length of time tagged and/or the involved.

cott (1949) reported that rock bass were frequently in very poor ion as a result of mandible strap tags. Rose (1949) and Patter- 953) found that strap tags on the maxillary of pikeperch exerted ding influence on growth.

he purpose of this study was to determine the effect of mandible gs on growth of five species of fish in different New York waters. ecies studied were: smallmouth bass *(Micropterus dolomieui),* trout *(Salvelinus fontinalis),* landlocked salmon *(Salmo salar),* trout *(Salmo trutta),* and rainbow trout *(Salmo gairdneri).*

METHODS AND MATERIALS

netter (1936) described the jaw-tag method of tagging fish. He No. 3 strap tag and made it oval in shape after application by g pressure at both ends. This resulted in a tag loosely encircling ndible bone of a fish in the same manner as the present mandible g.

NG

gure 1 shows the type of tag used in this study and its place- n fish. It is otherwise marketed as a hog ring tag, and its use es was first mentioned by Vladykov (1950). The tags are made nel metal and are of various sizes depending on the size of the be tagged. Two sizes were used in this study. The smaller

Figure 1. The small-sized mandible ring tag used in this study showing placement on a rainbow trout.

tag measures 35.5 by 3.2 by 0.5 millimeters and weighs 440 milligra The larger or medium-sized tag has the same width and thickness is 57.7 millimeters long and weighs 745 milligrams. A still lar sized tag is also available (76.5 millimeters long) but was not c sidered in this study. Hereafter, the tags are referred to as smal medium. All tags used were supplied by the Salt Lake Stamp C pany, Salt Lake City, Utah.

If jaw tags do have an effect on growth of fish, it would reflected in growth in length and/or weight after tagging. A t measurable effect exists in the condition factor.

Analysis of Data

In this paper only differences in length and condition are c sidered. Comparisons in weight were treated in the thesis manusc on file in the Cornell University Library; however, significant di ences in weight generally paralleled those in length, hence these c are omitted in the interest of brevity.

Data from the several sources were not all taken in the s manner and, therefore, were not subject to the same type of anal The following methods of analysis were used.

Method A. Regression of length at recapture on length at tagging was used where several age groups and one environment were involved. The same type of regression was used by Lindner (1953) to modify Walford's (1946) growth transformation technique to determine the growth rate of animals of unknown ages. This type of regression represents only the tagged portion of a population. For comparison with untagged members of the same population, the mean length of a single age group at the time of recapture is plotted against the mean length of the same age group at time of tagging if the interval of time was less than a year. If the interval was one year, the mean length of consecutive age groups at the time of tagging is used.

The resultant point represents the growth transformation of the untagged portion of the population. The regression line represents the tagged portion. The standard *t*-test is used to detect any difference between two means. One mean is the mean length of untagged fish at the time of recapture. The other is an adjusted regression mean; this is adjusted to the abscissal value of the point representing the untagged fish. The standard deviation for a difference of the two means is given by the formula:

$$s_{\bar{d}} = \sqrt{s_{\bar{y}}^2 + s_{y \cdot x}^2 \left[1/n + (\bar{x}_u - \bar{x}_t)^2 / Sx^2\right]} \quad \text{(equation 1)}$$

where:

$s_{\bar{y}}^2$ = the mean variance of length of untagged fish at the time tagged fish are recaptured (age $n+1$);

$s_{y \cdot x}^2$ = the variance from regression for tagged fish;

$1/n$ = the reciprocal of the sample size for tagged fish;

$\bar{x}_u$ = the mean length of untagged fish at the time fish are tagged (age n);

$\bar{x}_t$ = the mean length of tagged fish at the time of tagging;

Sx^2 = the corrected sum of squares for length of tagged fish at the time of tagging.

Method B. Analysis of variance to test treatment difference between lengths or condition factors for tagged and untagged fish was used where only one age group and one environment were involved.

Method C. Analysis of variance to test treatment and environment difference between lengths and condition factors for tagged and untagged fish was used where one age group and more than one environment were involved.

The condition factor also can be used as an indication of ta affect. Condition factors were determined by the usual formula:

$$K=\frac{10^5 W}{L^3}\text{(equation 2)}$$

where:

K=condition factor
W=weight
L=length

Condition factors of tagged versus untagged fish are considered colle tively.

Two length measurements have been used: fork and total. Ear data for smallmouth bass were recorded in fork length; worn fins the case of hatchery rainbow trout necessitated the use of this measur ment. All measurements were made on boards graduated in tent of an inch. Some weights were taken on Chatillon spring scal graduated in ounces (bass) or tenths of a pound (salmon). Othe were taken on platform spring scales with capacities of two or fi pounds and graduated in hundredths of a pound (trout).

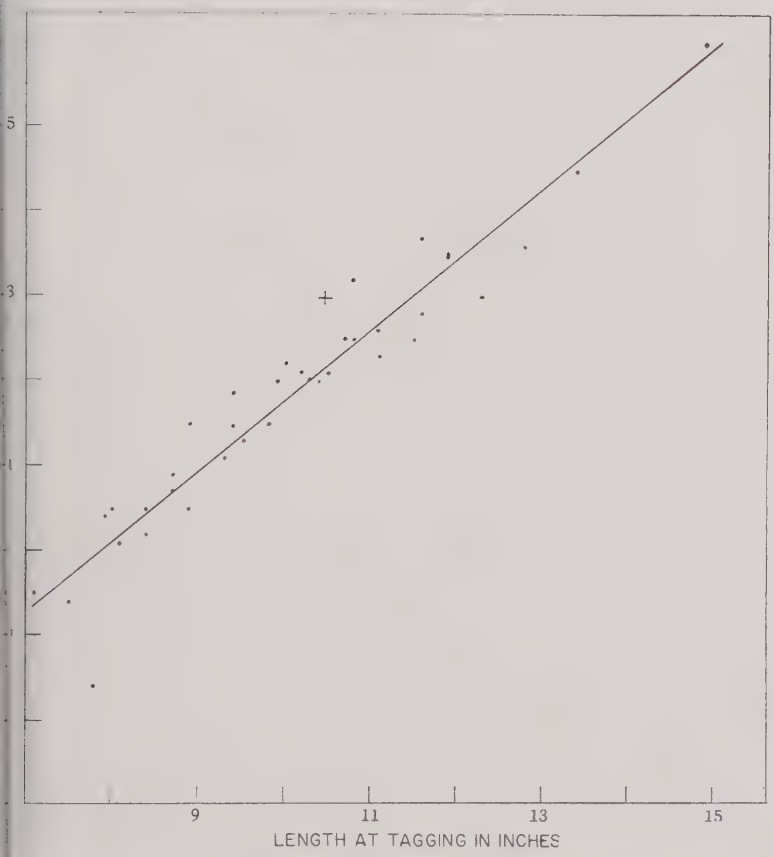
EFFECT OF TAGS ON LENGTH INCREMENTS

The effects of tagging on length increments are given for eac species studied. Smallmouth bass and landlocked salmon were analyze by method A, brook trout and brown trout by method B, and rainbo trout by method C.

Smallmouth Bass

Data for smallmouth bass were taken from files compiled for study of this species in Cayuga Lake by Webster (1954). Collectio of specimens was by fall angling or trap netting, and fish were tagge with the medium-sized tag. The range in the interval betwee tagging and recapture was 320 to 398 days; the mean was 375 day Thirty-seven bass tagged in 1951-52 and recaptured in 1952-53 we used. These specimens were distributed among six age groups makin it necessary to use the regression method (A) of analysis. Figure gives the regression of length at recapture on length at tagging.

The untagged members of the population are represented by point (+ in Figure 2). This point was derived by plotting the mea length of age V+ bass against that of age IV+ bass. Twenty bass each age were taken haphazardly from each of the 1952 and 195



re 2. Regression of length at recapture on length at tagging for smallmouth bass tagged for one year, Cayuga Lake, 1951-1953. Equation for line: $Y = 3.504263 + 0.825620X$. Dots represent original observations; cross represents mean length of untagged bass in age groups IV+ and V+.

bles, giving a total of 40 for each age group. Data from two years used to obtain a better estimate of the length of untagged fish including some year class variation.

These two mean lengths represent the length at age n ($10.44\pm$) and that at age $n+1$ (12.98 ± 0.155). If desirable, additional nts could be plotted following the method of Walford (1946). The n difference between tagged and untagged fish at the mean length ge $n+1$ is the vertical distance between the mean length of the gged fish (+) and that of the tagged fish (regression line). The

latter value, determined in this case by substituting $Y=10.44$ in the regression equation (Figure 2) is 12.15 inches, the adjusted mean length of the tagged bass.

The standard deviation for a difference between the two means, computed from equation (1), was 0.176. The t-test comparison becomes:

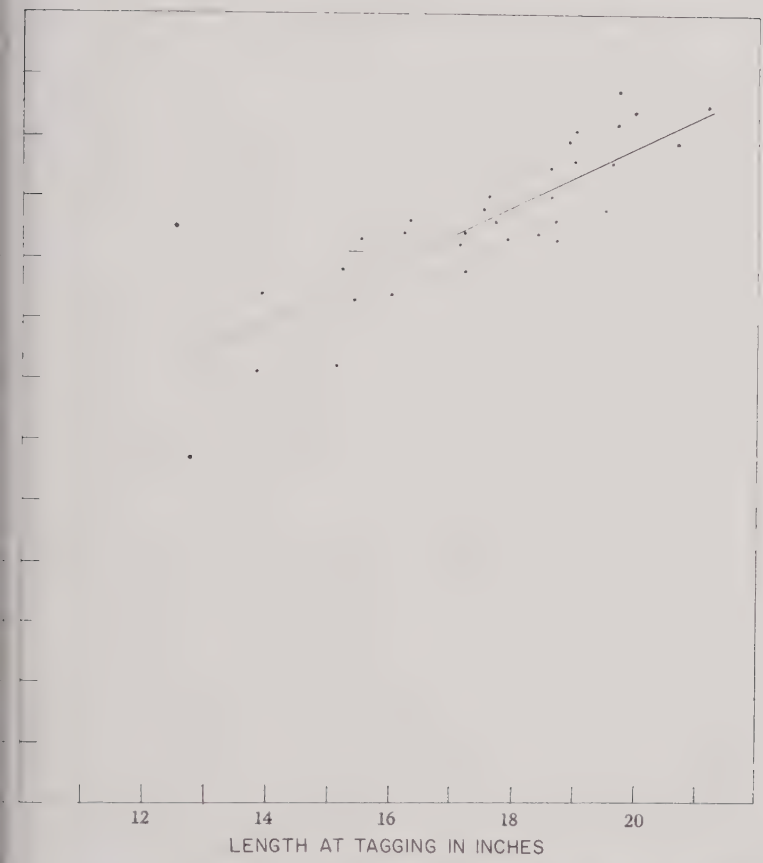
$$t=\frac{12.98-12.15}{0.176}=4.71$$

This value is significant at the 1 per cent level ($t_{.01}=2.75$, $n=30$), and it is concluded that tagged fish made significantly poorer growth. The mean difference in length was 0.84 inch, or 6.9 per cent of the length at the time of tagging.

Landlocked Salmon

Tagged salmon in Little Moose Lake provided information on this species. Little Moose Lake is located on the Adirondack League Club Preserve in Herkimer County. Fifty-nine salmon, tagged for one year with the medium-sized tag, were recaptured from 1953 to 1956. Method A of analysis was again used since more than one age was represented in the collection of tagged fish. Sexes have been compared separately because of differential growth. The regressions for length at recapture on length at tagging for male, female, and juvenile salmon are given in Figures 3, 4, and 5.

The point to represent the untagged portion of the population is more difficult to determine for salmon than for smallmouth bass. Tagged salmon were at large for a year before recapture. Therefore consecutive ages would normally be appropriate. However, the life history of salmon complicates the situation. Salmon in Little Moose Lake spend one or two summers in the outlet nursery stream before migrating to the lake; age at migration greatly affects the size attained in the lake in successive years. Two plantings of marked hatchery fish, made as yearlings and 2-year-olds, showed comparable divergence of growth. Larger fish also matured first (Webster, 1955). It is necessary to follow the same life history type in a single year class of salmon for two consecutive years to obtain an appropriate point. This was accomplished by using only salmon marked by fin clipping and stocked as yearlings in June 1953. Recoveries of these fin-clipped salmon in the falls of 1954 and 1955 were used to determine points representing length increments of untagged salmon.



e 3. Regression of length at recapture on length at tagging for tagged male landlocked salmon, Little Moose Lake, 1952-1956. Equation for line: $Y = 11.260338 + 0.475787X$. Dots represent original observations; cross represents mean length of untagged fin-clipped male salmon in 1954 and 1955 (planted as yearlings in 1953).

The mean length of untagged female salmon (+ in Figure 4) cated at the extreme left end of the regression line. The explana- is that the tagged female fish that happened to be recovered were r than untagged females in the fin-clipped 1952 year class.

Mean length of tagged salmon has been adjusted by regression to) inches, the mean total length of fin-clipped salmon recovered 954. This represents juvenile salmon taken in 1954 or length at n. By the time of collection in 1955 (at age $n+1$) part of the ipped salmon had matured and showed differential growth of

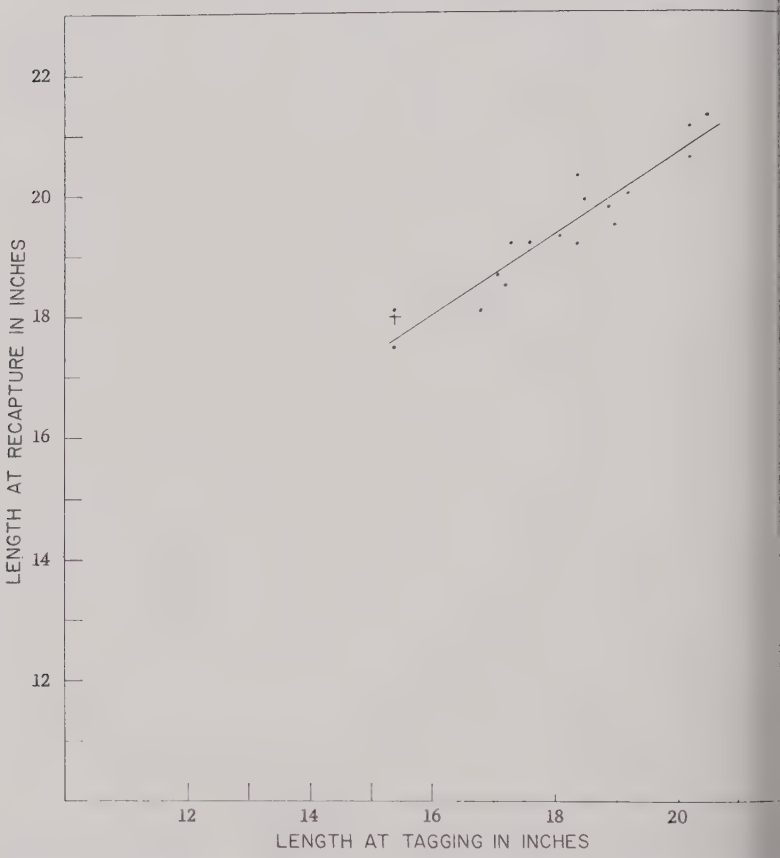
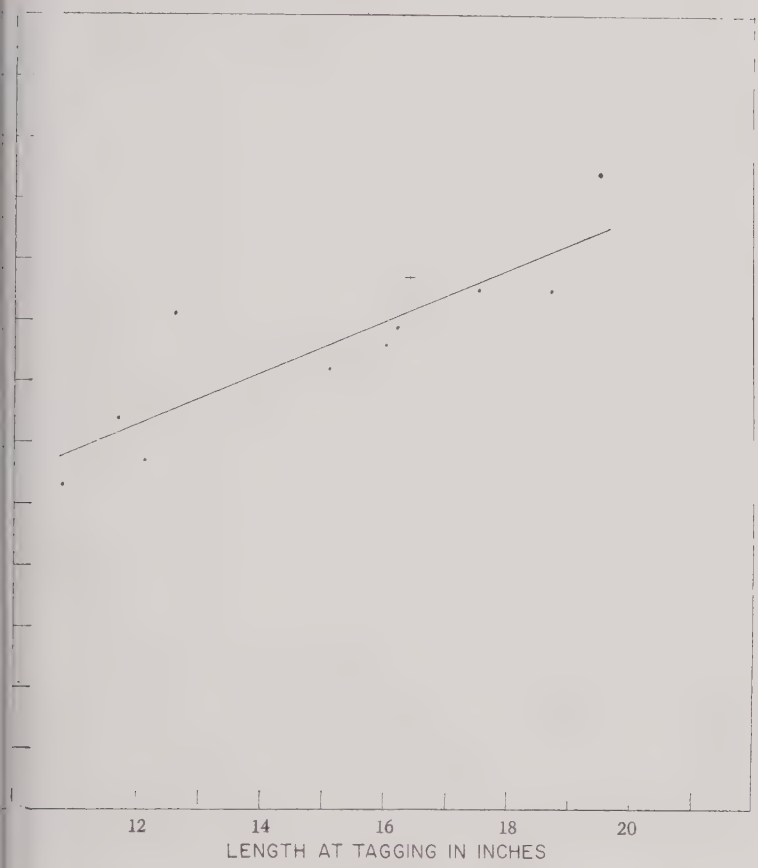


Figure 4. Regression of length at recapture on length at tagging for tagg female landlocked salmon, Little Moose Lake, 1952-1956. Equati for line: $Y = 7.412801 + 0.662835X$. Dots represent original obser tions; cross represents mean length of untagged fin-clipped fem salmon in 1954 and 1955 (planted as yearlings in 1953).

sexes thereby giving different mean lengths for male, female, a juvenile fish. Comparisons of length for tagged and untagged salm are given in Table 1, the statistics being computed in the same mann as for smallmouth bass. Tagged salmon showed significantly slow growth for males, females and juveniles, as measured by length.

Brook Trout

The effect of mandible ring tags on brook trout was studied three lakes: East Lake, Long Pond, and Follensby Jr. Pond. E



e 5. Regression of length at recapture on length at tagging for tagged juvenile landlocked salmon, Little Moose Lake, 1952-1956. Equation for line: $Y = 11.604292 + 0.424997X$. Dots represent original observations; cross represents mean length of untagged fin-clipped juvenile salmon in 1954 and 1955 (planted as yearlings in 1953).

is located on the Adirondack League Club Preserve. Long Pond Tollensby Jr. Pond are located on the Brandon Preserve in Franklin ıty.

East Lake East Lake was reclaimed by treatment with rote- in the fall of 1954. Yearling brook trout were restocked in the g of 1955. Small-sized mandible ring tags were placed on part e trout and the balance were fin-clipped. Trap nets were fished e fall of 1955. The recaptures from this netting were used in this

Table 1. Comparison of Total Length (inches) of Tagged and tagged Landlocked Salmon from Little Moose Lake, 1952-1

Item	Male	Female	Juvenile
Number of specimens	32	17	9
Value of Y in regression equation	11.260338 $+0.475787X$	7.412801 $+0.662835X$	10.65124 $+0.47957$
Untagged salmon: mean length and standard deviation	19.10 ± 0.553	18.00 ± 0.622	18.72 ± 0.4
Tagged salmon: mean adjusted length and standard deviation	18.59 ± 0.729	17.62 ± 0.355	18.04 ± 0.5
Mean difference	0.51	0.38	0.68
Standard error of difference	0.158940	0.169729	0.212419
Value of t	3.21**	2.24*	3.20*

* Significant at the 5 per cent level.
** Significant at the 1 per cent level.

Only one age group is involved so a direct comparison betw tagged and untagged trout can be made (method B). The year trout matured and spawned in the fall of 1955 making sexes discern (Webster, 1955). Lengths of brook trout from East Lake, trap ne between October 22 and November 13, 1955, are summarized Table 2.

Table 2. Mean Total Length (inches) of Brook Trout from E Lake in Fall, 1955

Sex	Tagged			Untagged		
	Number	Mean length	Standard deviation	Number	Mean length	Standa deviati
Male	6	8.70	0.502	27	9.35	0.61
Female	12	8.66	0.452	36	8.83	0.60

The data suggest a possible differential growth of the sexes. analysis of variance for lengths of untagged male and female br trout gave an F value of 11.41, indicating a highly significant differe between sexes ($F_{.01}=7.08$). This substantiates the observations m

natchery fish by Haskell and Griffiths (1956) and others. On this s, the sexes have been compared separately.

Analysis of variance for lengths of tagged and untagged male k trout gave an F value of 5.72, indicating a significant difference he 5 per cent level ($F_{.05}=4.16$). But the mean difference in ths of females is not significant. However, the trend was the same oth groups (tagged fish tended to be smaller) and the difference een tagged and untagged females may be regarded with suspicion.

LONG POND Long Pond was reclaimed with rotenone in ust of 1955. The pond was stocked with fin-clipped fingerling k trout in October of the same year. Some fish from this stocking tagged with the small-sized mandible ring tag in the fall of 1956. net recaptures in the fall of 1957 are summarized in Table 3. nod B of analysis is appropriate since only one age was involved.

E 3. MEAN TOTAL LENGTH (INCHES) OF BROOK TROUT FROM LONG POND IN FALL, 1957

Sex	Tagged			Untagged		
	Number	Mean length	Standard deviation	Number	Mean length	Standard deviation
.....	10	13.31	0.461	14	13.53	0.694
le.....	7	12.63	0.431*	26	13.06	0.615

The mean length difference between sexes was significant ($F=$ at the 5 per cent level ($F_{.05}=4.10$) necessitating separate com- ons for male and female fish. Analysis of variance for these data ed that the difference in mean length between tagged and gged fish was not significant for either males or females.

FOLLENSBY JR. POND Yearling brook trout were stocked in nsby Jr. Pond in the spring of 1956. All were marked by the val of the right ventral fin. In addition, small-sized tags were d on some of the stocked trout. Trap nets were fished on mber 25 and 26, 1956, and the following information was ned on marked trout.

	Number	Mean total length	Standard deviation
Tagged trout	11	10.17 inches	0.847
Untagged trout	13	10.42 inches	0.755

At the time of sampling the sexes of these brook trout could be distinguished externally.

Analysis of variance for lengths of tagged and untagged tr showed the difference to be non-significant.

Brown Trout

Brown trout were stocked April 3, 1956 in Cascadilla Ca (Tompkins County) to study the effect of mandible ring tags on tr in a stream environment with poor food conditions. The study a adjoined the Cornell Experimental Fish Hatchery where angling prohibited.

Two hundred yearling brown trout were marked by the remo of the adipose fin, half of which were also tagged with the small-si tag. Total lengths were obtained for all fish and tagged fish w weighed.

These trout were sampled by electro fishing on May 15 and 1956.

The mean total length at time of stocking was 7.23 ± 0.638 inc for tagged trout and 7.17 ± 0.597 inches for untagged trout; the m difference is non-significant. Following are the mean total leng in the sample 6 weeks later.

	Number	Mean total length	Standard devia
Tagged trout	22	7.48 inches	0.833
Untagged trout	31	7.35 inches	0.832

There was no significant difference between lengths of tagged a untagged brown trout. It is concluded that tagging had no measura affect on growth during the time lapse of 6 weeks, although grow was minor during this period for all fish.

Rainbow Trout

The effect of mandible ring tags on rainbow trout was studied 390 fall fingerlings stocked in six farm ponds in the vicinity of Itha Half of these trout were tagged with the small-sized tag. To avoid b with respect to the mean size of either tagged or untagged tro groups of 50 were alternately counted out and either tagged or untagged. Urethane was used on trout that were tagged to expe handling; untagged trout were treated with urethane for an eq length of time to avoid possible differential effect.

The rate of stocking was 300 trout per acre; half of the approe number were tagged. The average size of the ponds was 0.2 with a range of 0.1 to 0.3 acre. All trout were stocked on October 955. Five of the ponds contained no fish prior to stocking; one contained some brook trout. A letter was sent to each pond r asking his cooperation in not fishing the pond until the beginof May 1956.

During the period April 20-28, 1956, all ponds were seined using)-foot, ½-inch stretched mesh, cotton bag seine. The ponds were d again on June 4 and 6, 1956, but one pond was omitted due gh water temperature.

The ratio of tagged to untagged trout recovered by the first ng is a test for possible differential mortality of the two groups. ratio (see Table 4) did not differ significantly ($\chi^2 = 2.035$) from tocking ratio (1:1), indicating no differential mortality over the nth period.

Data from the second seining could theoretically be biased by ng selectivity; pond owners being aware of this study might to return tagged trout. Selection for larger trout would also be rce of bias since untagged trout were larger on the average than d trout. Larger untagged trout may also have been more vulnerto angling. However, there was apparently no bias from any of sources since the ratio of tagged to untagged trout recovered ning (see Table 6) again did not differ significantly ($\chi^2 = 0.439$) the original stocking ratio (1:1).

4. MEAN FORK LENGTH (INCHES) OF RAINBOW TROUT IN SIX FARM PONDS DURING THE PERIOD APRIL 20-28, 1956

Pond	Tagged			Untagged		
	Number	Mean length	Standard deviation	Number	Mean length	Standard deviation
eld.....	14	7.91	0.558	18	8.12	0.964
.....	24	6.50	0.730	26	7.31	0.609
erger....	38	7.90	1.105	41	8.40	0.785
.....	8	7.04	0.731	13	8.18	0.691
.....	35	6.93	0.775	37	7.58	0.691
.....	22	6.44	0.557	20	6.71	0.548

The mean length of rainbow trout for the first seining is g in Table 4. Analysis of these data (method C) showed a hi significant retarding effect of tagging on growth of rainbow trou these ponds (Table 5). Growth differences between ponds were highly significant. The non-significant interaction, however, sugg that the growth ratio of tagged to untagged trout remained the s from pond to pond.

Table 5. Analysis of Variance for Lengths of Tagged and Unta Rainbow Trout during the Period April 20-28, 1956

Source of variation	Degrees of freedom	Sum of squares	Mean square	Value F§
Tagged *vs.* untagged.....	1	23.76	23.76	39.6
Ponds.....	5	97.95	19.59	32.7
Interaction.....	5	4.50	0.90	1.5
Error.....	284	170.18	0.599	

§ $F_{.01}=6.76$, with 1 and 200 degrees of freedom.
$F_{.01}=3.11$, with 5 and 200 degrees of freedom.

The mean lengths of rainbow trout for the second seining given in Table 6. Analysis of these data confirmed all the foreg conclusions.

Table 6. Mean Fork Length (inches) of Rainbow Trout in Five F Ponds during the Period June 4-5, 1956

Pond	Tagged			Untagged		
	Number	Mean length	Standard deviation	Number	Mean length	Stand devia
Cooper.....	25	7.34	0.706	25	8.21	0.6
Ettenberger....	43	8.78	1.010	42	9.39	0.7
Harvey.....	13	8.01	0.905	10	8.89	0.4
Wells.....	41	7.89	0.781	40	8.53	0.6
Wilbur.....	21	7.40	0.728	20	7.98	0.6

Species	Untagged			Tagged			Mean difference	Mean square	Value of F
	Number of specimens	Condition factor		Number of specimens	Condition factor				
		Mean	Standard deviation		Mean	Standard deviation			
Smallmouth bass	34	9.86	1.126	34	9.73	1.199	0.13	1.352	<1
Landlocked salmon									
Male	38	33.03	1.480	32	31.26	2.597	1.77	5.622	9.75**
Female	27	37.29	2.139	17	36.30	3.025	0.99	6.138	1.60
Juvenile	16	29.26	1.544	9	30.78	4.315	1.52	8.032	1.66
Brook trout									
East Lake									
Male	27	39.56	3.294	6	40.97	7.404	1.41	17.94	<1
Female	36	41.53	2.732	12	39.32	5.088	2.21	11.87	3.73
Long Pond									
Male	14	44.69	4.024	10	45.70	2.816	1.01	5.97	<1
Female	26	45.91	2.608	7	47.01	4.000	1.10	6.58	<1
Follensby Jr. Pond	13	34.63	3.241	11	34.56	1.970	0.07	74.94	<1
Brown trout	31	44.99	4.709	22	43.30	4.744	1.69	22.31	1.64

** Significant at the 1 per cent level.

EFFECTS OF TAGGING ON CONDITION

Comparisons of condition factors for smallmouth bass, landlo salmon, brook trout and brown trout are shown in Table 7. Condi factors for individual fish have been computed from equation with the exception of smallmouth bass. In that instance the cons of 10^3 was substituted for 10^5 in the equation for convenience. random sample of 34 untagged smallmouth bass was taken fro untagged bass having the same size range as tagged bass. For o species all available data were used.

As seen in Table 7, the difference between condition factors tagged and untagged fish was significant in only one of ten com sons. The indication is that, although length (and weight) ma

Table 8. Mean Condition Factors for Rainbow Trout in Farm Po during the Periods April 20-28 and June 4-5, 1956

Pond and treatment of fish	April			June		
		Condition factor			Condition fac	
	Number of specimens	Mean	Standard deviation	Number of specimens	Mean	Stand deviat
Chatfield						
Tagged....	14	42.81	4.306	—	—	—
Untagged..	18	41.95	3.225	—	—	—
Cooper						
Tagged....	24	40.42	2.667	25	33.30	2.74
Untagged..	26	40.74	3.826	25	33.76	2.29
Ettenberger						
Tagged....	38	44.62	4.064	43	35.39	2.35
Untagged..	41	46.37	4.164	42	36.27	2.55
Harvey						
Tagged....	8	47.12	5.959	13	36.02	1.73
Untagged..	13	45.46	4.785	10	32.95	1.86
Wells						
Tagged....	35	37.60	3.379	41	35.37	2.48
Untagged..	37	38.16	3.135	40	35.04	2.33
Wilbur						
Tagged....	22	39.18	4.312	21	37.78	3.87
Untagged..	20	40.25	3.850	20	36.52	3.44

icantly different, the condition of tagged fish is representative e population in most cases. There is, however, a general tendency ondition factors of tagged trout to be smaller in most instances. may be a reflection of the smaller size of tagged fish rather than al difference in condition since the condition factor typically ases with size.

Condition factors of rainbow trout as computed from equation (2) ummarized in Table 8. Analysis of these data (Tables 9 and 10) ates that the difference between condition factors of tagged and gged fish is not significant for the April sample but is significant he June sample. This change in significance can be explained e differential growth of tagged and untagged trout. It is apparent Table 8 that condition factors decreased rapidly from April to

9. ANALYSIS OF VARIANCE FOR CONDITION FACTORS OF TAGGED AND UNTAGGED RAINBOW TROUT IN FARM PONDS DURING THE PERIOD APRIL 20-28, 1956

urce of variation	Degrees of freedom	Sum of squares	Mean square	Value of F§
d *vs.* untagged.....	1	2.29	2.29	<1
.....	5	2843.74	568.74	38.56
ction.....	5	75.17	15.03	1.02
.....	284	4188.99	14.75	

$F_{01}=3.11$, with 5 and 200 degrees of freedom.

10. ANALYSIS OF VARIANCE FOR CONDITION FACTORS OF TAGGED AND UNTAGGED RAINBOW TROUT IN FARM PONDS DURING THE PERIOD JUNE 4-5, 1956

rce of variation	Degrees of freedom	Sum of squares	Mean Square	Value of F§
d *vs.* untagged.....	1	34.99	34.99	5.09
.....	4	336.07	84.02	12.21
ction.....	4	88.66	22.17	3.22
.....	270	1857.78	6.88	

$_{05}=3.89$, with 1 and 200 degrees of freedom.
$_{01}=3.41$, with 4 and 200 degrees of freedom.
$_{05}=2.41$, with 4 and 200 degrees of freedom.

June. Since condition is a function of length, the fact that the tagged trout were growing significantly faster seems to account the difference noted. Interaction also follows the same pattern be significant in June but not in April. This indicates that the ratio condition factors for untagged to tagged trout changed from pond pond.

DISCUSSION

Tagged fish in this study grew slower than untagged fish for species investigated with the exception of brown trout. However, the latter the interval between tagging and recapture was only 6 we

In view of the results of this study it seems advisable to be cauti in interpretating growth data from fish with mandible tags. Wh feasible, an investigator should determine the effect of mandible t on the particular species in the given area. If any difference in gro is demonstrated, data from tagged fish may be adjusted.

The effect of mandible ring tags on fish may be influenced many factors. Among these are amount of food available in particular body of water, size of fish at time of tagging, and spe of fish being tagged. Stroud (1953) suggested that differences obser among jaw-tagged fish may vary with method of feeding and f available. No data in the present study are appropriate for such comparison. More experiments with tagged and untagged fish un controlled growth rates would be necessary for verification. Sch (1942) found that large and small brown trout were equally han capped by mandible ring tags. The size range he studied was appro mately 6-12 inches. No other work on tag effect in relation to size has come to the writer's attention.

In natural situations where mandible ring tags do cause a red tion in growth a secondary effect may exist, i.e., mortality due to p dation. Slower-growing fish might remain as potential food lon and thus might have a higher mortality rate from predation. Obviou the importance of this will depend on the size of the fish at tagg and the relation of this size to predation in that particular situati In this study use of mandible ring tags resulted in no differen mortality in rainbow trout stocked in farm ponds. Stroud (19 found no mortality due to maxillary strap tags on yellow perch i stocked pond. However, both of these situations were somew artificial in that no other species or size groups of fish were pres nor were fish predators likely much of a problem. In the Adiron ponds, predation from fish-eating birds and mammals is much grea

the absolute retardation in growth is probably not enough to ly influence differential mortality from this source.

Erosion and inflammation of the mandible are two physical re- sometimes caused by mandible ring tags. Erosion may be great gh in some cases to wear completely through the dentary bone and tag loss. Such evidence of tag loss was noted in three rainbow stocked in farm ponds. Tag loss was also noted on one brown trout ed in Cascadilla Creek. Mandible erosion may also provide an nce for secondary infection. Several rainbow trout had inflamed around the tag but no record of the number was kept. On the hand, numerous recaptures of tagged brook trout and salmon failed to disclose much evidence of this type of injury in these s.[2] This may have been due to the larger size of these fish at ng. Smith (1957) reported a high degree (28 per cent) of tag or brook trout held in a pond 248 days as opposed to no tag or brook trout held in another pond for 108 days; but he did inch his tags.

Other effects that warrant investigation are behavior of tagged ulnerability of tagged fish to various methods of capture, and lity over various periods of time. Cooper and Benson (1951) an unequal return by angling for tagged and fin-clipped fish d in equal numbers under the same conditions. This indicates a nce in vulnerability as far as angling is concerned, a serious quence if tag returns are to be used in computing rates of tation.

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STIMATION OF CATCH AND RELATED STATISTICS OF THE STREAM RAINBOW TROUT FISHERY OF THE FINGER LAKES REGION[1]

Wilbur L. Hartman Research Assistant
Department of Conservation, Cornell University

ABSTRACT

A creel census was conducted during the opening week of stream fishing rainbow trout in the Finger Lakes region in 1955, 1956, and 1957. Estimates total catch and related statistics were derived from the collected data.

Catches ranged from 140 trout in 1957 at Cold Brook (Keuka Lake inlet) 980 in 1955 at Catherine Creek (Seneca Lake inlet). More fish were caught ening day than on any succeeding day.

Opening-day fishing pressure at Catherine Creek ranged from 360 to 640 glers per mile of stream. It was considerably less at the other streams.

Of the 19,646 anglers contacted in the three years, only 1,652 (8.4 per nt) caught fish. Highest fishing success occurred at Grout Brook (Skaneateles ke inlet); lowest at Catherine Creek.

Data on the distribution of fish among successful fishermen permitted an aluation of the present creel limit of five fish. It did not function in restricting catch. If it is found desirable in the future to further limit exploitation of rainbow trout spawning runs, the creel limit would not become an effective ans until reduced to two fish.

Rainbow trout of the Finger Lakes region of New York are taken angling mainly during the spawning season in the tributary streams. atistics on total catch, fishing pressure, fishing success, and the distribution of the catch are desirable in a study on the biology and anagement of the species in this area. The general scope of the program, conducted jointly by the New York State Conservation Department and Cornell University, has been described by Hatch (1957), one and Hartman (1957), Hartman (1957), and Webster (1957).

The author thanks Dr. Dwight A. Webster, Professor of Fishery Biology, Cornell University, who originally designed the creel census and reviewed the manuscript. Dr. W. M. Lawrence, Assistant Commissioner for Fish and Game; Dr. C. W. Greene, Chief, Bureau of Fish; and A. J. Vormwald, Chief, Bureau of Law Enforcement, all of the N. Y. S. Conservation Department, were instrumental in putting the census into operation. District Game Protectors Hanville, Cone, Callaghan, and Moore, and their men, made all field contacts during the census. Data on the recapture of tagged fish reported to heir offices were supplied by District Fisheries Managers U. B. Stone and A. C. Petty.

PROCEDURE

Four tributary streams were involved: Grout Brook (Skane Lake inlet), Catherine Creek (Seneca Lake inlet), Cold Brook (H Lake inlet), and Naples Creek (Canandaigua Lake inlet).

Since a complete census was not possible, a means of estim statistics of total catch and fishing pressure was necessary. Thi provided as a by-product of routine tagging of a sample of the sp ing population. Estimates of the tagged: untagged ratio of fi the anglers' catch were obtained in a partial creel census cond by State game protectors who regularly patrolled the streams d the opening week of the season.

Game protectors were instructed to contact as many fishe as possible. Forms were provided for recording the following information: (1) unsuccessful fishermen contacted, (2) fish c by individual successful fishermen, and (3) tagged fish checked d the census.

The census was not expected to be complete; the catch by fi men not contacted was unknown. But tags reported by mail t Department (hereafter referred to as tag-letter returns) we measure of this unknown catch. The following proportion was to estimate the total catch:

$$\frac{\text{total tags recovered}}{\text{census tags recovered}} = \frac{\text{total catch (unknown)}}{\text{total census catch}}$$

In most situations samples were large enough so that estimates reliable. "Total tags recovered" comprised the combination of census tag reports and tag-letter returns.

Similarly, total fishing pressure was estimated from:

$$\frac{\text{total tags recovered}}{\text{census tags recovered}} = \frac{\text{total number of fishermen}}{\text{fisherman contacted in census}}$$

Few tags were reported from Cold Brook and Naples Cre 1956, and useful estimates of the total catch and fishing pressure c be made.

Reporting tags by letter was voluntary, and there was no w determining the percentage of unreported tags. Hence estimat the total catch and fishing pressure are minimum. Comparis catches between different streams seems valid, assuming that the percentage of fishermen (not contacted in the census) volun reported tags from each stream.

FINDINGS

Most of the basic data used in deriving estimates of the catch id related statistics are given in Table 1.[2]

ABLE 1. CREEL CENSUS DATA FROM WHICH ESTIMATES OF THE CATCH AND MOST OF THE RELATED STATISTICS WERE DERIVED

Stream	Year	Fishermen contacted	Successful fishermen	Checked catch	Tags reported	
					Creel census	Tag letter
out Brook	1955	580	213	384	16	8
	1956	576	109	184	18	9
	1957	710	115	153	28	8
therine Creek	1955	7,095	386	577	47	32
	1956	3,669	186	263	14	17
	1957	2,216	141	185	13	37
ld Brook	1955	802	60	132	26	4
	1956	1,119	81	115	0	1
	1957	656	98	129	33	3
ples Creek	1955	541	100	133	5	3
	1956	932	92	122	2	6
	1957	750	71	101	10	14
tal		19,646	1,652	2,478	212	142

IE CATCH

The daily catches actually checked in each of the four streams presented in Figure 1 as the percentages of the opening week's ch taken each day. More fish were caught opening day than on succeeding day. In all cases more than half of the opening week's ch was taken in the first two days of fishing, although the catch in out Brook was somewhat more dispersed.

Estimates of the total opening-week's catch in each of the four ams are given in Table 2. The yield from Catherine Creek was stantially above those from the others, with an estimated high

he opening-week creel censuses were incomplete in the following instances: 1) only the first three days were censused at Cold Brook in 1955; (2) the xth day of the opening week was not censused at Grout Brook in 1956; 3) only the first five days were censused at Catherine Creek in 1957; 4) only the first, second, and fifth days were censused at Cold Brook in 957. These inconsistencies do not greatly restrict the general usefulness of e data.

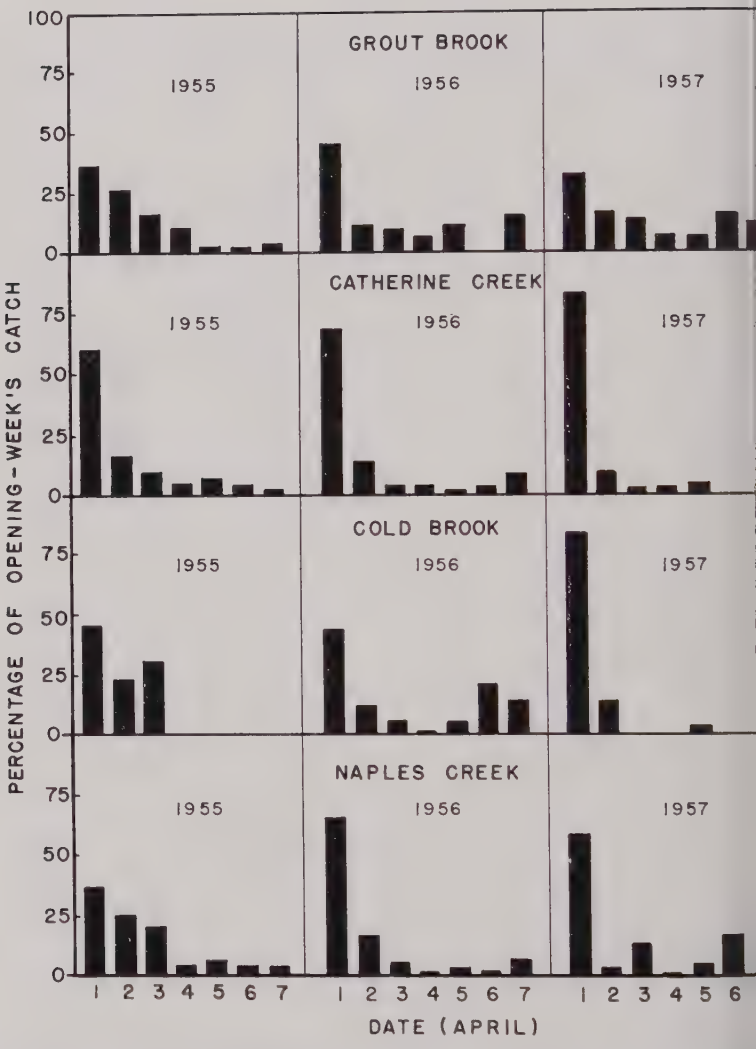

Figure 1. Daily percentages of the opening-week's catch in each strea 1955, 1956, and 1957.

catch of nearly 1,000 trout in 1955. The other three streams prod much smaller catches, generally between 100 and 300 fish.

Fishing Pressure

The total number of fishermen was estimated using the me

ABLE 2. ESTIMATES OF THE TOTAL OPENING-WEEK'S CATCH OF RAINBOW TROUT

Year	Grout Brook	Catherine Creek	Cold Brook	Naples Creek
55	540	980	160	210
56	280	580	*	*
57	200	700	140	240

* Insufficient data for reliable estimate.

scribed. It can be assumed that during the census game protectors trolled the most heavily fished portions of the streams. According notations on the daily summary sheets, about 5 miles of Grout ook, 11 miles of Catherine Creek, 4½ miles of Cold Brook, and ¼ miles of Naples Creek were covered. This included most of the ut fishing mileage of the four streams.

Estimates of opening-day fishing pressure are given in Table 3. shing pressure was heaviest at Catherine Creek each year, ranging m 365 to 635 anglers per mile of stream. There was considerably s pressure at the other three streams, seldom more than 100 fisher- n per mile. After the opening day, fishing pressure decreased sharply.

BLE 3. ESTIMATES OF OPENING-DAY FISHING PRESSURE IN 1955, 1956 AND 1957, EXPRESSED AS THE NUMBER OF FISHERMAN PER MILE OF STREAM

Item	Grout Brook			Catherine Creek			Cold Brook			Naples Creek		
	1955	1956	1957	1955	1956	1957	1955	1956	1957	1955	1956	1957
hing ressure	50	75	90	485	365	635	115	*	125	25	*	70
glers ontacted pening lay	171	249	349	3,122	1,815	1,840	427	*	511	204	*	398

* Insufficient data for reliable estimate.

SHING SUCCESS

Fishing success is defined as the percentage of fishermen catching n. In this survey it was based on the sample of fishermen contacted

Table 4. Daily Fishing Success in 1955, 1956 and 1957, Expressed Percentage of Fisherman Checked Who Caught Fish

Date	Grout Brook			Catherine Creek			Cold Brook			Naples C	
	1955	1956	1957	1955	1956	1957	1955	1956	1957	1955	1956
April 1	42	17	12	7	7	6	8	6	16	18	10
2	34	22	22	4	6	5	6	11	13	15	19
3	35	18	20	4	4	8	8	5	—	27	7
4	34	24	43	4	4	10	—	1	—	25	4
5	37	22	40	7	3	15	—	8	8	23	8
6	36	—	16	6	4	—	—	13	—	12	4
7	33	17	19	4	2	—	—	7	—	20	7
Average. . . .	37	19	16	5	5	6	7	7	15	19	10

during the creel census. Table 4 gives daily fishing success at the f streams over the 3-year period.

Highest average fishing success occurred at Grout Brook (16 37 per cent). Catherine Creek had the lowest fishing success (5 per cent). This likely reflected the tremendous fishing pressure th Not only were large numbers of fishermen competing for a ca generally limited to 1,000 or less fish in the opening week, but s pressure probably further reduced individual success by decreas fishing efficiency.

Despite the large opening-day harvests, Table 4 shows that fish success was generally maintained at the same level throughout opening week for any stream in any year. One, or a combination the following reasons may explain this: (1) reduced fishing press after the opening day reduced competition for the remaining f (2) it also probably resulted in greater individual fishing efficien (3) the average caliber of fishermen that continued to fish after opening day may have been higher; (4) stream population may h been augmented with fresh-run fish.

Distribution of the Catch

Table 4 shows that, on the average, only once during the th years were more than 19 per cent of the fishermen successful (Gr Brook in 1955). In other words, most fishermen did not catch f

Figure 2 gives the percentages of successful fishermen in e stream each year that caught one, two, three, four or five fish. M of the successful fishermen caught only one or two fish. The distri tion was similar for the different streams and years.

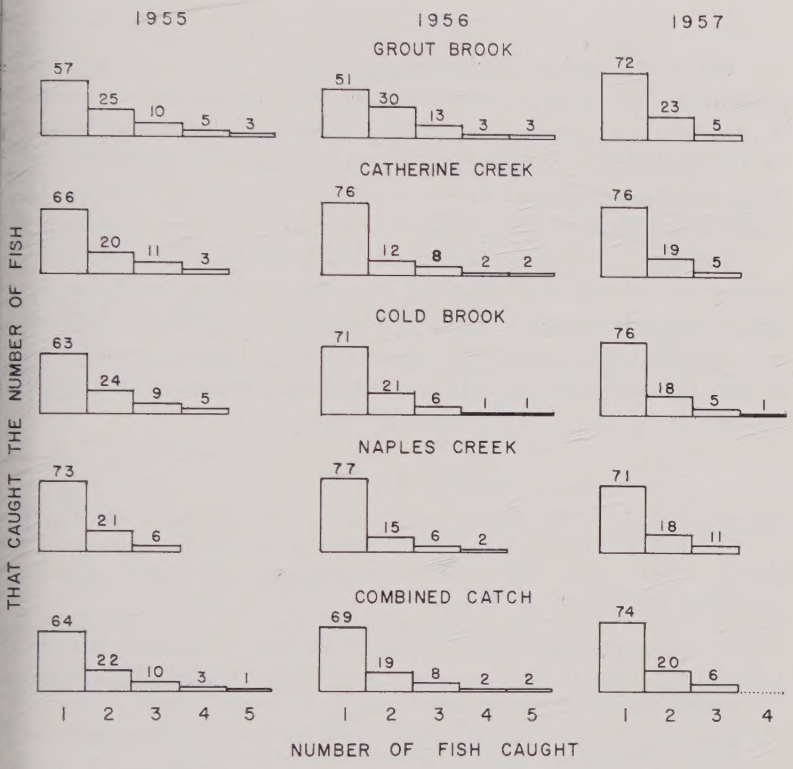

Figure 2. Distributions of the catch among successful fishermen in 1955, 1956, and 1957. Daily bag limit at all four streams was five fish.

The most important application of the catch distribution is evaluation of the present creel limit of five fish per day from April 1 to May 15.[3] Limit catches were reported at Grout Brook in 1955 and 1956, and at Catherine Creek and Cold Brook in 1956. Since only per cent of all fishermen in 1955, 2 per cent in 1956, and 0 per ent in 1957 caught the creel limit, it did not function in restricting he catch. Further, no significant reductions in the catch would be btained by setting the creel limit at three fish. Only 4 per cent of he successful fishermen in 1955 and 1956, and 1 per cent in 1957 aught more than this number. The creel limit would become a more ffective means of restricting the catch when set at two fish. As yet, owever, there is no evidence that it would be desirable to further mit exploitation of the spawning runs in this manner.

[3] Applies to these and certain other specified streams in the Finger Lakes region.

DISCUSSION

While the method used for estimating the total catch and fish pressure has the disadvantage of relying on voluntary tag-letter retu the expansion of creel census data is probably sufficiently accurate fix the magnitude of these statistics. Reliability is obviously rela to the numbers of tagged fish recaptured and reported. Fiducial lir could be attached to the estimates if desirable (Ricker, 1937).

Tag and recapture data for each stream are unsuitable for e mating the size of the spawning populations. Recruitment of fre run, untagged fish into the population spawning in the tributa was probably adequate to alter significantly the tagged: untagged ra at the time of sampling. This shortcoming is irrelevant in the use the tag recoveries for estimating total catch and effort.

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